CA4 ONHBL W49
82 A36

URBAN/MUNICIPAL

HAMILTON PUBLIC LIBRARY
FEB 5 1987
GOVERNMENT DOCUMENTS

REPORT ON

HIGH-VOLUME PARTICULATE SAMPLING

QUALITY ASSURANCE

URBAN AIR ENVIRONMENT GROUP

McMASTER UNIVERSITY

AIR QUALITY MONITORING SECTION

REPORT ON

HIGH-VOLUME PARTICULATE SAMPLING

QUALITY ASSURANCE

SUMMARY

The overall precision of measurement of TSP data was estimated to be 7.8 percent of the calculated mean annual [1981-82] Hamilton TSP concentrations. This level of precision is considered to be adequate, as measurement agreement with Ontario Ministry of the Environment (OME) is very good. Calculated errors of estimates of mean annual PSD-derived mass median diameter (MMD) are less than 10 percent of Hamilton's mean annual MMD levels, and are acceptable for use in long-term human exposure studies.

TABLE OF CONTENTS FOR

AIR QUALITY MONITORING SECTION, HIGH-VOLUME PARTICULATE SAMPLING AND QUALITY CONTROL MEASURES

		PAGE
PART 1	INTRODUCTION	1
PART 2	ASSESSMENT OF DATA QUALITY	3
2.1	Flow Rate of Sample Air	3
2.1.1	TSP	3
2.1.2	PSD	7
2.2	Sample Duration	9
2.2.1	TSP	9
2.2.2	PSD	10
2.3	Net Loading	10
2.3.1	Balance Accuracy and Stability	11
2.3.2	Particulate Collection Surface Mass Stability	14
2.3.2.1	Effect of Handling	15
2.3.2.2	Effect of Storage	16
2.3.2.3	Adjustment For Relative Humidity	20
2.3.2.4	Recommendations	26
PART 3	INTERLABORATORY COMPARISON	88
PART 4	SAMPLING SUCCESS RATES	90
PART 5	SUMMARY OF TSP SAMPLE MEASUREMENTS	94
PART 6	SUMMARY OF PSD SAMPLE MEASUREMENTS	99

Table of Contents (Cont'd)

		PAGE
PART 7	HIGH-VOLUME SUSPENDED PARTICULATE SAMPLING SUMMARY . . .	103
PART 8	REFERENCES	105

LIST OF TABLES

1. Effect of Variable Measurement Precision
2. Effect of Variable Combinations on Particulate Concentrations
3. Effect of Flow Measurement Precision
4. Concentration Variable Transformation
5. Regression ANOVA Table
6. Transformation of Static Pressure Readings to Achieve Linearity
7. Regression ANOVA Table
8. Summary of TSP Calibration Regressions
9. Summary of Individual TSP Calibration ANOVAs
10. Inter-Year Calibrated Flows by Sampler
11. Two-way Analysis of Variance Between Samplers and Years
12. TSP Calibration Summary By Site and Date
13. Summary of Inter-Year Calibration ANOVAs
14. Precision of Flow Chart Reading
15. Analysis of Variance for Sample Flows and Observers
16. PSD Flow Stability Data
17. ANOVA Table of PSD Pre- and Post-Sampling Static Pressure Drops
18. Relationship Between PSD Flow Rate, Line Voltage and Static Pressure Drop
19. PSD Flow vs Static Pressure Drop Regression ANOVA Table
20. Effect of Flow Precision on Total PSD Concentration
21. Effect of Time Measurement Precision
22. TSP Concentration vs Time Measurement Regression Analysis of Variance
23. Time Reading ANOVA Data

24. Time Reading ANOVA Table

25. TSP Concentration vs Net Loading Regression ANOVA Table

26. Effect of Net Loading

27. Analyses of Balance Zeroing and Standard Weights

28. Summary of Environmental Factors

29. Summary of Simple Linear Regressions of Balance Zero and Standard Weight

30. Multiple Regression of Standard Weight By Humidity and Temperature

31. Multiple Regression Model Predicted Standard 1.0 g Mass Measurements

32. Hi-Vol Filter Reweigh Statistics

33. Effect of Handling on Filter Mass

34. Summary Statistics of Control Filter Mass Observations

35. Summary Statistics of Collection Surface Masses and Associated Environmental Factors

36. Summary of Collection Surface Masses Regressed by Analytical Variables

37. Summary Statistics of Stepwise Multiple Regressions of Collection Surface Masses

38. Simple Linear Regression of Surface 1 Storage Types by Environmental Predictors

39. Summary Statistics of Stepwise Multiple Regressions of Collection Surface 1 Masses

40. Summary of Difference Statistics for Days and Humidities

41. Mass of Theoretical Surface for Various Levels of Humidity

42. Measured Net Particulate Loadings of TSP and PSD Collection Surfaces

43. Transformation of an Invalid PSD Sample Using Humidity Adjustment

44. Effect of Humidity on Calculated PSD Sample Net Loading and Concentration

45. Effect of Humidity on Calculated PSD Sample Cumulative Percent Loading and Mass Median Diameter

46. Summary Statistics of Humidity Measurements Using Hygrograph and Sling Psychrometer

47. TSP Interlaboratory Comparative Results

48. Summary of Sample Validity Status

49. Summary of Measurement Precision for TSP Variables

50. Effect of Measurement Precision on TSP Concentration

51. Summary of PSD Measurement Variable Precisions

52. Effect of Measurement Precisions on Mean PSD Concentrations

LIST OF FIGURES

1. Quality Control and Assurance Project Schedule

2a. Flow Chart of TSP Quality Assurance and Control
2b. Flow Chart of PSD Quality Assurance and Control

3a. TSP Concentration vs Sample Air Flow
3b. Log of Concentration vs Sample Air Flow

4. Static Pressure vs Air Flow

5. Field Calibration Curve: Red Hill Creek Site 1979-01-30

6. Field Calibration Curve: Red Hill Creek Site 1979-02-01

7. Relationship of PSD Flow Rate to Static Pressure Drop

8. TSP Concentration vs Time Measurement Precision

9. TSP Concentration vs Net Particulate Loading

10. TSP Network (UAEG) Operational Site Summary

11. PSD Network Operational Site Summary

PART 1

INTRODUCTION

High-volume (hi-vol) suspended particulate samples were collected using commercially available instruments. Total suspended particulate (TSP) samples were collected by 18 instruments using the standard reference method designated by the United States Environmental Protection Agency (Code of Federal Regulation, 1975) and Environment Canada (1973). Particle size distribution (PSD) sampling was conducted using nine commercial hi-vol units modified to reduce the sample air flow rates, and equipped with Andersen 2000 Inc. four-stage, multi-orifice cascade impactors. Each glass fibre impaction collection surface, or filter, was weighed before and after exposure to sample air to determine the gravimetric net particulate loading for each size category. The flow rate and duration of air sampling were measured and used to calculate the particulate concentration.

Figure 1 presents the quality control and assurance work schedule. Figures 2a and 2b graphically depict the variables required to calculate particulate concentrations, and the procedures that validated these individual variables. The calculations required for TSP and PSD were identical, except that individual calculations were required for each of the five PSD size ranges. The general formula for calculation of particulate concentration is as follows:

$$PC = [(W_2-W_1)*10^6] / [F/(35.315*T)],$$

where PC = particulate concentration (ug/m^3 = micrograms per cubic meter),

W_1 = unexposed weight of filter (grams),

W_2 = exposed weight of filter (grams),

F = air flow measured (cubic feet per minute),

10^6 = conversion factor from grams (g) to micrograms (ug),

35.315 = conversion factor from cubic feet per minute (cfm) to cubic meters per minute,

T = sampling time (minutes).

It is apparent from this equation that the measurement variables subject to quality control were sample air flow rate, sample duration, and filter weight. Table 1 presents the effects of measurement precisions for these variables on calculated final concentrations. Calculated concentrations vary directly with net particulate loading, but inversely with air flow rate and sampling duration.

Table 2 presents calculated particulate concentrations with different combinations of variables within the ranges of the respective measurement precisions.

PART 2

ASSESSMENT OF DATA QUALITY

2.1 FLOW RATE OF SAMPLE AIR

2.1.1 TSP

The effect of flow measurement precision on the calculation of final particulate concentration is illustrated in Table 3. Errors at low flow rates had a greater effect on final concentration than errors of identical magnitude at higher flow rates. The mean flow rate for 16 TSP samplers was calculated to be 48.4 cfm, with a standard deviation of 4.7 cfm. If, for example, the flow was underestimated by 5 cfm, the concentration would have been overestimated by 5.5 ug/m^3 (Table 1).

Figure 3 shows the effect of variation in measurement precision on calculated TSP concentrations. Table 4 illustrates the transformation of the concentration values used to achieve linearity; Table 5 shows the analysis of variance (ANOVA) from the linear regression displayed in Figure 3b. From Figure 3b, the estimated logarithm of the concentration decreased linearly with increasing air flow.

Air flow measurement for TSP sampling was measured and recorded continuously by Dickson recording transducers. Individual

transducers were calibrated in the field annually, or whenever the blower-transducer combination was disrupted by breakdown. Field calibrations were performed using a portable calibration orifice assembly and a water manometer. The orifice assembly-water manometer combination was calibrated against a positive displacement meter which read out directly in "true" cubic feet of air. Figure 4 is the curve drawn to convert displacement meter readings to manometer static pressure readings. Table 6 presents the actual static pressure readings (Pm') and the transformed pressure readings (Pm) used to achieve linearity. The regression line is presented in Figure 4 for the transformed variable; its associated ANOVA is shown in Table 7. From Figure 4, it is apparent that the estimated pressure logarithm increased linearly with increasing flow.

Figures 5 and 6 are examples of field calibration curves used to adjust flows recorded by the transducer to "true" flows, determined by static pressure readings. The orifice assembly-manometer combination was considered a secondary standard, and ensured that flows recorded by each transducer were comparable. During each individual calibration, transducer readings and static pressure readings were recorded. The static pressure readings were then converted into "true" flows, which were then plotted against the recorded flows. Table 8 summarizes the simple linear regression analyses of the individual calibrations performed. In all cases, the slope was positive and significantly different from zero [$p<0.05$], with the indicated

reading increasing with true flow. The mean slope of the 66 regressions, excluding the invalid calibration from Mt. Albion [May 8, 1981], was 0.976, with a standard deviation of 0.158, indicating that the transducer readings varied directly and proportionately with true flow. The y-intercepts represented the calculated actual flows when the indicated flow readings were zero; they varied from 28.3 to 39.6. The mean y-intercept for the 66 calibrations was 6.3, with a standard deviation of 9.971 and a range of 67.9. The p-value variation indicated that the transducers were not always accurately "zeroed" and were not sufficiently consistent to allow use of a constant value for correction calculations.

Table 9 summarizes the results of analysis of variance performed for each calibration. The p-values calculated for variation due to orifice plate were less than 0.01, with only two exceptions. Mount Albion [May 8, 1981] had a p-value of 0.07; this calibration was recognized immediately as being inaccurate and was redone on May 22, 1981. San Diego [December 1979] had a p-value of 0.015. The p-values representing variation between recorded and "true" flows exhibited much greater variation than those values associated with orifice plates, indicating that a single correction could not have been applied to all transducers, and that, therefore, individual instrument calibration was required. The coefficients of determination were greater than 94% in all cases and had a mean of 99.2%. This indicated that almost all variation was explained by the orifice plate or calibration

procedure variations.

As mentioned previously in this Section, each tansducer was calibrated at least once per year, or whenever the blower-transducer combination was changed. Table 10 presents operational, calibrated flows for seventeen separate TSP samplers for the years 1980 and 1981. The mean difference between the years was 0.03 cfm with a standard deviation of 2.2 cfm.

An analysis of variance (Table 11) indicates that there were strong differences among flows recorded at the sites [$p<0.001$], but no statistically significant differences detected between years 1980 and 1981 [$p>0.999$].

Table 12 is a summary of TSP calibration dates by site. The ellipses drawn around successive dates indicate that the blower-transducer combination remained intact at that site during these periods. An analysis of variance was carried out to compare successive calibrations; the results are summarized in Table 13. The calculated p-values for the comparison between indicated and actual flows were generally less than 0.001, indicating a strong difference between the two readings. The p-values for the calibration [indicated and actual Year 1, compared to the indicated and actual Year 2] vary greatly. Significant differences [$p<0.05$] between yearly calibrations were detected in 27 cases. In eleven of these cases, the motor-transducer combination was disrupted, and in twelve instances the motor

brushes were replaced between calibrations. Future studies are planned which will include the effects of ambient temperature, barometric pressure and wind speed in an attempt to further explain discrepancies between calibrations.

TSP sample air flow recording necessitated the reading of each individual flow chart. Table 14 presents the mean flow rates of 17 recordings as determined by three operators blind to each other. The mean of the standard deviations between operators was calculated to be 0.14 cfm. Table 15 presents the results of the analysis of variance procedure. There was a very strong difference [$p<0.005$] in flows recorded at different sites, but no differences were detected [$p>0.1$] among the three independent observers.

2.1.2 PSD

PSD sampler flow rates were calibrated using an oil-filled field manometer to measure the static pressure drop across the sampling head. This calibration was performed during the instrument servicing prior to every sample run. The blower motor speed was adjusted using a variable transformer to vary the voltage applied to the motor, to obtain a static pressure drop of 6.0 inches of water, corresponding to Andersen's factory flow calibration of 20 cfm. In order to assess flow stability during the sampling period, post-sample static pressure readings were obtained in addition to the standard pre-sample readings. A total of 31

matching pre- and post-sample static pressure readings were obtained from eight sites during April 1982. The cascade impactor sampling heads were rotated from instrument to instrument. The data collected during this study period are presented in Table 16.

An analysis of variance was conducted as a check on the sources and strengths of variation. The results of this analysis are presented in Table 17. The differences between individual samples were small and not significant [p = 0.5], while differences between the pre- and post-sample readings were detected [p = 0.019]. The coefficient of determination was 0.541, indicating that almost half of the total static pressure drop variation was unexplained by the individual samples or the pre-sample static pressure readings. The PSD samplers were not equipped with constant flow controllers; therefore, intermittent line voltage fluctuations would have caused the flow rate and static pressure readings to fluctuate accordingly, as shown in Table 18.

Figure 7 is a graphical presentation of the relationship between static pressure drop and measured "true" air flow. The regression ANOVA statistics are presented in Table 19.

The standard deviation of the differences between 31 pairs of pre- and post-sample PSD static pressure readings was shown to be 0.498 inches of water. This translated into 0.229 cfm, as calculated by the regression equation presented in Figure 7. Table 20

illustrates the effect of 0.229 cfm differences in flow rate on final calculated concentrations at three loadings. The resulting absolute change in concentration was greatest at high loadings [0.57 ug/m3]. At low loadings, the resulting change in calculated concentration was 0.07 ug/m3. The absolute value of the change in concentration varied with net loading, but amounted to only 1.1% of the concentration.

2.2 SAMPLE DURATION

2.2.1 TSP

Duration and flow rate of TSP sampling were recorded by Dickson transducer recorders using four-inch-diameter circular charts. These charts had a 15-minute-interval scale, readable to 5 minutes. The chart drive was a 110 VAC 60 Hz. clock motor. The effect of a five-minute reading error is illustrated in Table 21. Errors in reading sample duration were believed to account for less than 0.5 ug/m^3 of any typical final TSP concentration.

Figure 8 is a graphical presentation of the effect of time measurement precision on TSP concentration, with all other variables held constant. Increases in sample duration resulted in linear decreases in calculated TSP concentration due to a calculated increase in sample air volume. Table 22 presents the results of the linear regression ANOVA.

Since all flow recorder charts had to be read manually, an analysis of variance was undertaken to study the agreement of observers in determining sampling duration. A total of 17 charts and three operators were selected. The charts were read in random order and the operators were blind to each other. The results of the study and the subsequent analyses are presented in Tables 23 and 24. Strong differences were detected among the samples [$p<0.001$], but no differences [$p>0.1$] were detected among the independent operators. This implies that operator precision was very good, with an estimated standard deviation of 1.6 minutes.

2.2.2 PSD

Most PSD samplers were slaved to the adjacent TSP sampler's programmable timer. In this way, the TSP sample duration was also the PSD sample duration. In cases in which a TSP sampler was not available, the PSD sampler was equipped with a 60-cycle digital elapsed timer, reading to the nearest tenth of a minute.

2.3 NET LOADING

Particulate concentration was calculated by dividing the net particulate loading deposited on a collection surface, by the total volume of sample air. The net particulate loading was the difference between exposed and unexposed collection surface masses. Figure 9 graphically illustrates the effect of weighing

precision on TSP concentration, and Table 25 summarizes the results of the ANOVA of the regression analysis of the data presented in Table 26.

The regression model indicated that net particulate loading had a very significant effect [$p<0.001$] on TSP concentration. The net loading coefficient was 0.5, and the coefficient of determination was 1.00. The model predicted that a 1.0 mg change in mass (loading) would result in a 0.5 ug/m^3 change in calculated TSP concentration.

2.3.1 BALANCE ACCURACY AND STABILITY

All gravimetric measurements were made using a Mettler Gram-Atic Type B6 Analytical Balance, read to the nearest tenth of a milligram. The analytical procedure required that the balance be mechanically zeroed before each session to ensure an unloaded reading of 0.0000 g. At the completion of each analytical session, another unloaded measurement was recorded, without mechanical adjustment, to monitor drift in the instrumental zero. Balance accuracy and precision were monitored by weighing a Class "S" (U.S. National Bureau of Standards) 1.0 g standard mass immediately before and after each analytical session.

Table 27 presents a summary of balance accuracy and precision monitoring data recorded between 1982-03-25 and 1983-03-03. The pre-session zero was mechanically defined as 0.0000 g and had the

same mean, while the unadjusted post-session zero had a mean of 0.00001 g [SD = 0.0003]. No significant difference between pre- and post-session observations was detected by a two-tailed Student's t-test [p = 0.661], indicating good balance zero stability within sessions. Analysis of the 1.0 g standard mass data indicated that the balance agreed very closely with the recognized standard [mean = 1.00000 g], and had reasonable repeatability from session to session [SD < 0.00027 g]. No detectable difference within weighing sessions was noted by a two-tailed Student's t-test [p = 0.963].

All post-session zero and standard weight data were further analyzed using simple linear regression techniques to investigate possible relationships with observation day, the number of filters weighed each session, ambient humidity, barometric pressure (P_B), and temperature (^oC). Table 28 presents a descriptive summary of the environmental predictors. The weighing day value was the Julian date, the number of days after January 1, 1983, on which observations of instrument zero and standard mass were recorded. The humidity, barometric presssure and temperature values were recorded inside the balance chamber at 1200 hours on each observation day.

Table 29 presents the results of simple linear regression analyses using individual environmental variables as predictors of instrumental zero and standard mass. Temperature was the only significant predictor [p<0.005] of post-session zero. No

significant differences [$p>0.5$] in pre-session standard mass were detected for any of the other environmental predictors. Significant differences were detected for post-session standard mass when regressed by humidity [$p = 0.013$] and by temperature [$p = 0.009$].

Multiple linear regression techniques were used to test the relative predictive strengths of humidity and temperature interactions for post-session standard mass. The multiple linear regression results are summarized in Table 30. The variation in mass was only partially explained by both humidity and temperature [$R^2 = 12.1\%$], but both these factors were found to have a significant effect on the mass [$p<0.05$]. The humidity coefficient was positive, indicating that mass increased with humidity, whereas the temperature coefficient was negative, which indicates that mass decreased with increases in temperature. These interpretations were only valid when the remaining factor was held constant.

Table 31 presents the results of standard mass predictions based on the multiple regression model presented in Table 30, and the environmental data presented in Table 28. The predicted mass range was calculated to be 0.9 mg. Under normal seasonal conditions, the occurrences of minimum and maximum temperatures linked with, respectively, minimum humidity were concurrent. A minimum temperature-maximum humidity, or reverse, situation would have been a highly unusual occurrence; this suggested that the

predicted standard mass range would have been that less than 0.2 mg.

2.3.2 PARTICULATE COLLECTION SURFACE MASS STABILITY

Approximately 10 percent of all particulate collection surfaces were reweighed, both before and after exposure to sample air. Analyses of these data are presented in Table 32. Mean differences in the reweigh values varied between 0.0001 and 0.0005 g. Increases in mean difference were reflected in the calculated t-values for each filter type. Significant differences between reweigh values were detected for exposed Configuration I and II PSD collection surfaces. The rectangular filters used for collection of TSP and of the finest fraction of PSD, did not show significant differences in masses.

Rectangular filters, [Schleicher and Schuell Inc., Type #1-HV], were of continuous glass fibre mat construction, and were formulated to be resistant to damage from handling. The PSD sample Configuration I and II collection surfaces were manufactured as a continuous mat of binderless, non-hygroscopic glass fibre, before being punched out to produce holes corresponding to the cascade impactor plate holes. Loose punch-outs and fibres were observed on these collection discs. Filters were individually checked for these artifacts, which were removed prior to weighing: however, each handling of the disc caused more fibres to break from the surface.

The mean difference between exposed Configuration I and II reweighs was approximately 0.5 mg; typical particulate loadings were on the order of 10.0 mg. This resulted in a calculated error of approximately 4 percent.

2.3.2.1 Effect of Handling

Table 33 presents the results of a short-term study designed to investigate the effect of cumulative handlings on the mass of a rectangular filter. The first filter was removed from the balance chamber between weighings, while the second filter was left untouched between weighings. Simple linear regression of observed filter masses by cumulative number of weighings resulted in negative coefficients that were significantly different from 0.0 [$p<0.001$]. The coefficient associated with handled filters was approximately 20 times greater than that of the filter left untouched. The standard deviation of the handled filter was approximately 13 times that of the untouched filter mass. These results suggested that further investigation was required to determine if the effect of handling was significant.

The combined filter masses [$n = 80$] were regressed by the serial weighing number, and by a newly created dummy variable representing handling or no handling. It was found that the dummy variable provided a significant contribution to the regression function [$F(1,77) = 53.634$, $p<0.001$], implying that handling

resulted in a significant reduction in filter mass.

All particulate samples were collected and analyzed according to a protocal minimizing the number of handlings in order to reduce and standardize the effects of handling between samples.

2.3.2.2 Effect of Storage

A second study of collection surfaces was undertaken to evaluate mass stability over extended periods of time. Exposed sample collection surfaces were often stored for up to four months before exposed gravimetric analyses were completed. Surfaces 1 and 2 were rectangular filters. Surface 3 was a Configuration I cascade impactor surface. Filter 1 was stored horizontally, on an open shelf in the balance chamber, from 1982-03-21 to 1982-06-10. This filter was then stored inside a cardboard box from 1982-06-28 to 1982-11-25. Rectangular Filter 2 was stored vertically, on an open shelf, between 1982-07-22 and 1983-02-23. Surface 3 was stored vertically, on an open shelf, between 1982-12-01 and 1983-02-23. A summary of filter mass observations for each surface type is presented in Table 34.

All surface types experienced fluctuations in mass; significant differences [$p<0.05$] were detected between pre- and post-sample analytical sessions. Additional statistical analyses were undertaken to investigate possible relationships between changes in surface mass and monitored analytical factors. A summary of

environmental factors recorded each analytical day during the study period is presented in Table 35. Temperature and relative humidity, and barometric pressure were continuously monitored by a thermohygrograph and a barograph, respectively. The values for all environmental factors used for analysis were those recorded at 1200 hours on the appropriate analytical day.

Table 36 presents a summary of simple linear regression results. When all surface masses combined were regressed by individual environmental factors, strong differences [$p<0.005$] in mass were detected for temperature, humidity, day, and surface type predictors, but only weak differences [$p<0.05$] in mass were detected for the barometric pressure predictors.

The effect of surface type was controlled by regressing individual collection surface masses by environmental predictors. Two dummy variables were created to represent the storage conditions experienced by Surface 1. The mass of Surface 1 was significantly affected [$p<0.001$] by humidity, weighing day, and storage type, but no significant effects [$p>0.1$] were detected for temperature or barometric pressure predictors. Simple linear regressions of Surface 2 masses detected strong effects [$p<0.001$] for humidity, barometric pressure, and day predictors, and a weak effect [$p<0.05$] for the temperature predictor. Surface 3 masses, when regressed by individual factors, were strongly influenced [$p<0.001$] by humidity and weighing day, weakly influenced [$p<0.05$] by temperature, and not detectably influenced [$p>0.918$] by the

barometric pressure predictor.

Stepwise multiple linear regression analyses were performed to determine the relative influences of all the interactive analytical factors on collection surface mass. The results are presented in Table 37. When all surface masses were combined, the fitted model contained significant coefficients [$p<0.05$] for surface type and humidity, while the regression model explained 66.0 percent of surface mass variability. The effect of surface mass type was controlled by fitting a stepwise multiple regression model for each surface. The Surface 1 multiple regression model explained 89.3 percent of the variation in mass, and detected strong differences [$p<0.005$] for storage, humidity and day factors. The Surface 2 multiple regression model detected a highly significant effect [$p<0.001$] due to humidity, with the model explaining 65.7 percent of the mass variability. The multiple regression model fitted to Surface 3 masses detected a highly significant effect [$p<0.001$] due to weighing day, with the model accounting for much of the mass variability [$R^2 = 82.4\%$]. Ambient temperature and barometric pressure were not significant predictors [$p>0.05$] of changes in mass for any of the surface models.

Table 38 presents simple linear regression results for Surface 1 by storage treatments. Storage Period A represented the period during which the surface was stored horizontally on an open shelf, while Storage B represented the period during which the filter was

stored inside a a cardboard box. For Storage Period A, temperature, humidity, and day were significant predictors [$p<0.005$] of Surface 1 mass. During Storage Period B, humidity, barometric pressure, and day were significant predictors of mass, although the coefficient of determination for the barometric pressure predictor model was only 18.5 percent.

Stepwise multiple linear regression techniques were used to investigate the interactions of analytical factors on Surface 1 masses by storage type. The fitted models are presented in Table 39. Controlling for storage conditions resulted in models with improved explanations of Surface 1 mass variability [R^2 = 99.4% and 82.0%, respectively]. Day and humidity remained highly significant predictors [$p<0.001$] during Period A, but temperature and barometric pressure were not significant contributors [$p>0.05$], and were deleted from the model. During Period B, ambient humidity was the only analytical factor detected to have a significant influence [$p<0.001$] on Surface 1 mass.

The multiple regression model for Surface 1A had significantly positive coefficients for weighing day and humidity predictors, suggesting that the mass of these surfaces increased directly with increases in storage time and ambient humidity. Multiple regression models for Surfaces 1B and 2 had significantly positive humidity coefficients, while the model for Surface 3 had a significant negative coefficient for weighing day. Humidity was a significant contributor to all the models, with the exception of

Surface 3, which did not experience as large a range of humidity as the other models (Table 40). Day had a significantly negative coefficient in the Surface 3 model, but a significantly positive coefficient in the Surface 1A model. The positive Surface 1A coefficient may have resulted from dustfall accumulations on the horizontal, unprotected surface. The negative day coefficient of the Surface 3 model could then be explained by mass losses due to handling effects, as presented in Table 33.

2.3.2.3 Adjustment For Relative Humidity

The Surface 2 multiple regression model was considered to be most representative of routine TSP and PSD monitoring samples. Surface 1 was not representative of routine storage conditions; the Surface 3 data base was small compared to the other models. The Surface 2 model was therefore chosen to illustrate a method of surface mass adjustment for changes in relative humidity (RH) between pre- and post-sample analytical sessions. The regression model, presented in Table 33, was of the form:

$$Yu = Bo + B1\ X1$$
$$= Bo + (0.0012)(RH)$$

Once this model was obtained, the measured unexposed mass [Yu = 4.0000 g] was adjusted for the measured relative humidity [X1 = 38.5] by removing its contribution and calling it Yua.

$$Yua = Yu - B1\ X1$$
$$= 4.000 - (0.00012)(38.5)$$
$$= 4.000 - 0.00462$$
$$= 3.99538$$

The collection surface was then exposed to a measured volume of sample air and reweighed to obtain the measured exposed surface mass [Ye = 4.1138 g], at an ambient relative humidity of 23.0 percent (X2). Since exposed surfaces were not fitted to a regression model, the only adjustment that could be made to exposed surfaces was the Surface 2 model, derived from unexposed filters. The adjusted exposed weight (Yea) would be:

$$Yea = Ye - B1\ X2$$
$$= 4.1138 - (0.00012)(23.0)$$
$$= 4.1138 - 0.0028$$
$$= 4.1110$$

In general, we expected exposed surface mass (Yea) to be greater than unexposed surface mass (Yua) due to particulate deposition (Zd). Particulate deposition adjusted for humidity (Zda) would be estimated by:

$$Zda = Yea - Yua$$
$$= Ye - Yu - B1(X2 - X1)$$
$$= Zd - B1(X2 - X1)$$

The fitted model for the example was therefore:

$$Zda = Yea - Yua$$
$$= 4.1110 - 3.99538$$
$$= 0.1156$$

OR

$$Zda = Ye - Yu - B1(X2 - X1)$$
$$= 4.1138 - 4.0000 - 0.00012(23.0 - 38.5)$$
$$= 0.1156$$

OR

$$Zda = Zd - B1(X2 - X1)$$
$$= 0.1138 - 0.00012(23.0 - 38.5)$$
$$= 0.1156$$

Fluctuating humidity implied that the humidity adjustment to net particulate loading would be positive, negative or zero, and would depend on the differences in the exposed minus unexposed humidities (X2 - X1). If the sign of the differences in humidities (X2 - X1) and the sign of the coefficient were the same, the humidity adjustment would be positive. The adjustment would be negative if the exposed humidity exceeded the unexposed humidity, zero if the humidities were the same, and positive if

the exposed humidity was less than the unexposed humidity.

Table 41 illustrates this effect for the masses of a theoretical surface, measured under different ambient humidities recorded in the balance room. A surface measured as 4.0000 g at 5.0% humidity would be expected to have a mass of 3.9994 g when adjusted to 0% humidity, while a 4.0000 g mass measured at 65% humidity would be adjusted to 3.9922 g.

In general, following seasonal changes, humidity increased from winter through summer, and decreased as summer passed to winter. This was of concern when samples were collected but could not immediately be analyzed gravimetrically. These seasonal trends would result in overestimates of net particulate loading for both TSP and PSD samples collected and analyzed during periods of increasing humidity [winter to summer]. Underestimates of particulate loading would be expected for samples collected during periods of decreasing humidity [summer to winter]. The largest overestimates would be associated with samples collected and analyzed in late winter or early spring, and analyzed in mid- to late summer. The largest underestimates of particulate loading would be expected for samples exposed in late autumn and analyzed during the winter months.

Table 42 presents descriptive statistics of net particulate loadings for TSP and PSD samples collected between 1981-04 and 1982-03, inclusive. The mean net loading for all TSP samples was

113.8 mg. Mean particulate loadings for PSD samples were 28.4, 7.7, 8.3, 11.9 and 21.5 mg, from fine to coarse size fractions, respectively. Negative PSD particulate loadings were measured for 20 separate samples collected during August [1], October [11], and November [6], 1981, and January, 1982 [2].

The following example illustrates the application of humidity adjustment to an actual PSD sample collected and analyzed under routine conditions. The five unexposed collection surface tare masses were individually measured on 1981-11-05, at a relative humidity of 40%. These surfaces were exposed to sample air on 1981-11-18 at Site 208. The exposed surface masses were measured 68 days later on 1982-01-12, at a relative humidity of 23 percent. All four exposed cascade impaction surface masses were found to be less than the tare masses previously measured, resulting in negative net PSD loadings. The regression model developed for reference Surface 2, and presented in Table 37, was applied to each measured PSD surface mass to remove the effects of humidity. The measured and humidity-adjusted PSD loadings are presented in Table 43. The humidity adjustments resulted in a relatively large decrease in tare masses, a smaller decrease in exposed surface masses, and a corresponding increase in the estimated PSD loadings. In this case, the adjusted PSD loadings were positive, and transformed an invalid sample into a valid sample.

Table 44 presents the results of routine primary data reduction and humidity adjustment of hypothetical samples whose tare and

exposed masses were measured at different humidities. Examples 1(a) and 1(b) were samples constructed to have relatively low net PSD particulate loadings, while Examples 2(a) and 2(b) were samples with average (refer to Table 42) net PSD particulate loadings. Type (a) Examples referred to surfaces whose unexposed masses, were measured at 40% relative humidity, and whose exposed masses, at 23%. Type (b) Examples were surfaces whose unexposed and exposed masses were measured at 23% and 40% relative humidities, respectively. Humidity adjustments resulted in increased PSD particulate concentrations in Examples (a), but decreased concentrations in Examples (b). Surfaces with relatively low net particulate masses experienced the greatest percentage change due to humidity adjustment. The greatest changes were associated with Examples 1(a) and 1(b), where differences in net loadings were as great as 53 percent.

Table 45 contains the calculated cumulative percentage less than size range, and estimated mass median diameter (MMD) figures for the hypothetical samples given in Table 44. The largest changes in cumulative percentage loading occurred in the 1.1-2.0 and 2.0-3.3 micron size categories. Again, the largest effects were associated with low net PSD particulate mass collection (Examples 1(a) and 1(b)). Differences between measured and adjusted cumulative percentages were as great as 16.2%. Samples with average net PSD particulate masses presented differences in cumulative percentages of less than 10.0 percent. The cumulative percentage less than size range figures were used to calculate the

mass median diameter of the PSD sample (Andersen, 1976).

The estimated mass median diameters were affected by humidity adjustment by as much as 11.0%, but this change was only 0.3 microns in absolute terms. The greatest effect was noted in the geometric standard deviations of measured and adjusted. Due to the fact that the MMD usually occurred in the size ranges most affected by humidity adjustment [the lightly-loaded, mid-sized particulate categories], the error in its estimation was lower than errors in estimates associated with smaller or larger particle size categories.

2.3.2.4 Recommendations

It appears that efforts must be made to reduce the effects of humidity and storage on collection surface mass. The effects of humidity may be controlled by:

1) Controlling ambient humidity within the storage-balance chamber;

2) Conducting weighing sessions during periods of stable relative humidity; or

3) Applying a statistically derived correction factor to mass measurements obtained during periods of fluctuating humidity.

Capital equipment costs and scheduling requirements associated with routine particulate monitoring precluded the implementation of options 1) and 2) during the course of this study. Additional data and analyses are required to determine the feasibility of adopting option 3), although it appears to be the most accurate and practical solution.

Additional measurements of reference surface masses are required to encompass a complete calender year. The humidity measurements must be further investigated to ensure the accuracy and precision of the data. Preliminary analyses of concurrent relative humidity measurements using a hygrograph and sling psychometer are presented in Table 46. A Student's t-test detected a significant difference [$p<0.001$] between hygrograph and psychrometer measurements. Simple linear regression of hygrograph on psychrometer measurements indicated that there was very little agreement between the two measurement methods at the time they were taken. The constant coefficient was calculated to be 0.18355, and was not detected to be significant [$p = 0.08$]. This implies that the hygrograph measurements did not vary significantly with changes recorded by the psychrometer. The hygrograph is now being calibrated by the manufacturer's service representative and will be the subject of further evaluation when it is returned.

The effect of storage duration appears to be less pronounced than

that of humidity. Storage effect may be minimized by:

1) Limiting storage time to a practical minimum through the establishment of a specific protocol; or

2) Providing dustfall protection to filters exposed in the chamber.

The protection required in option 2) may be as simple as storing filters vertically or inside their transport envelopes until the weighing is completed. All sample surfaces have been stored vertically since 1978. This option provides the technician with greater flexibility in terms of scheduling at no additional capital expense.

FIGURE 1

QUALITY CONTROL AND ASSURANCE WORK SCHEDULE

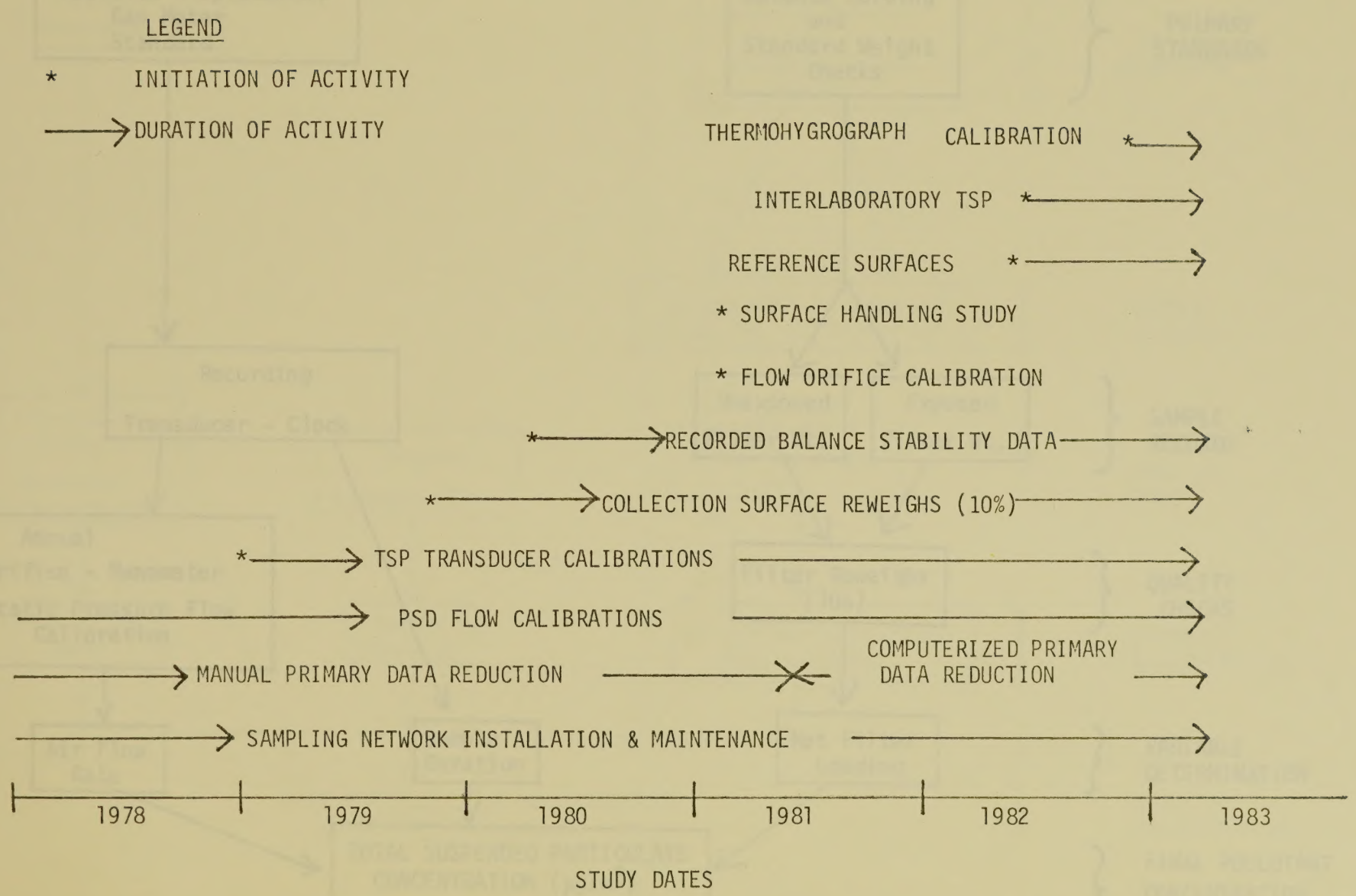


FIGURE 2a

FLOW CHART OF TSP QUALITY ASSURANCE AND CONTROL

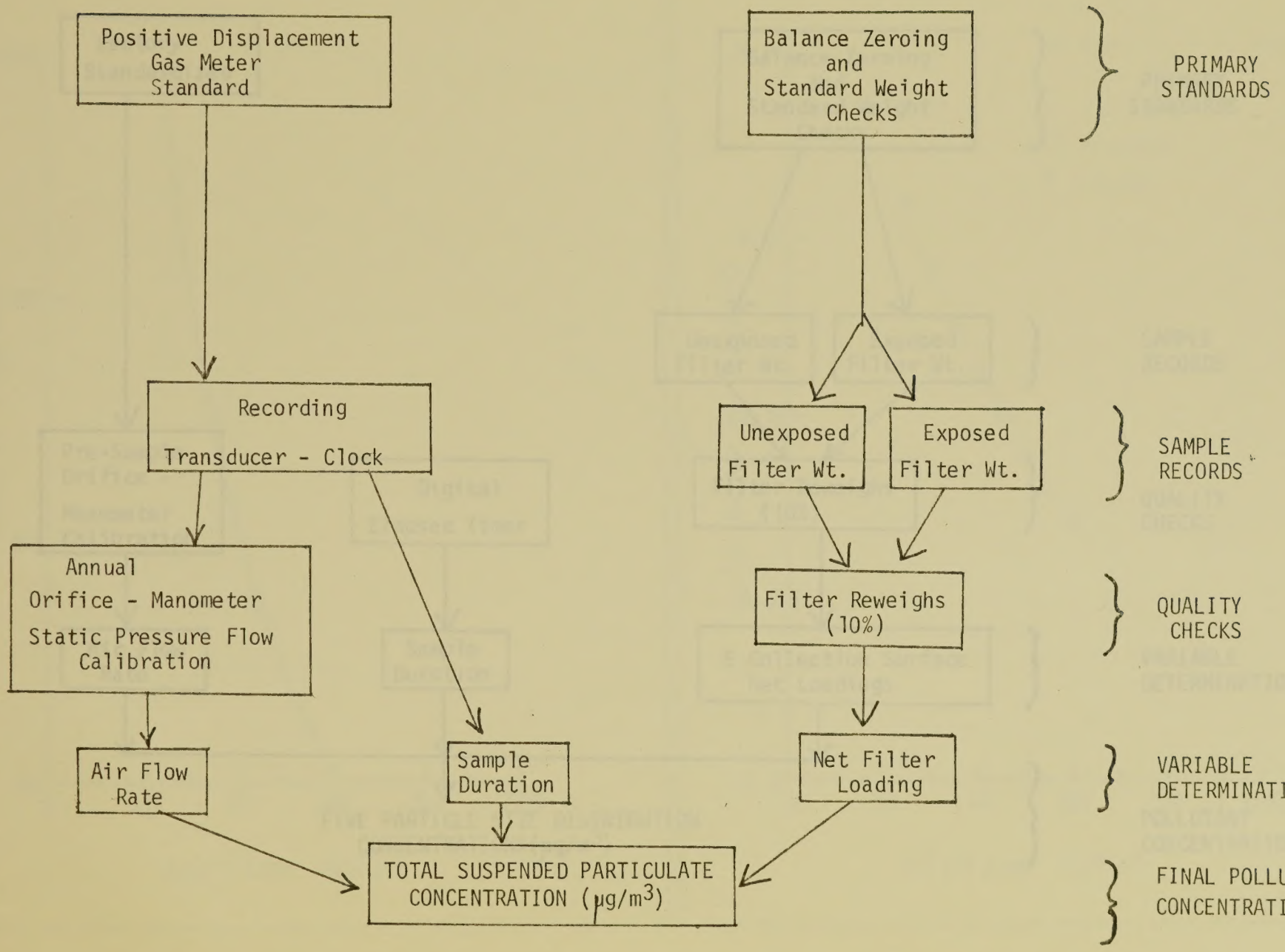
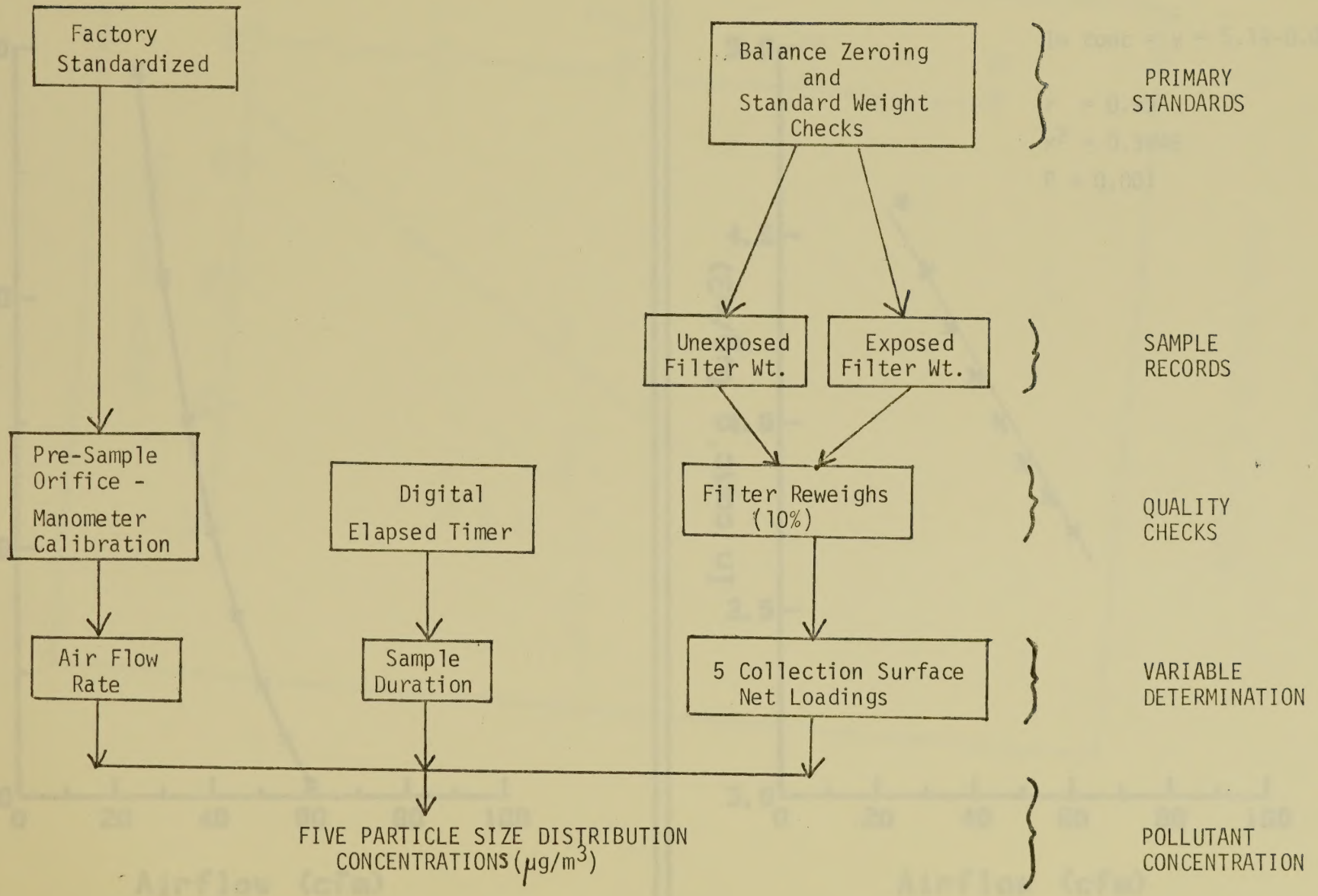


FIGURE 2b

FLOW CHART OF PSD QUALITY ASSURANCE AND CONTROL



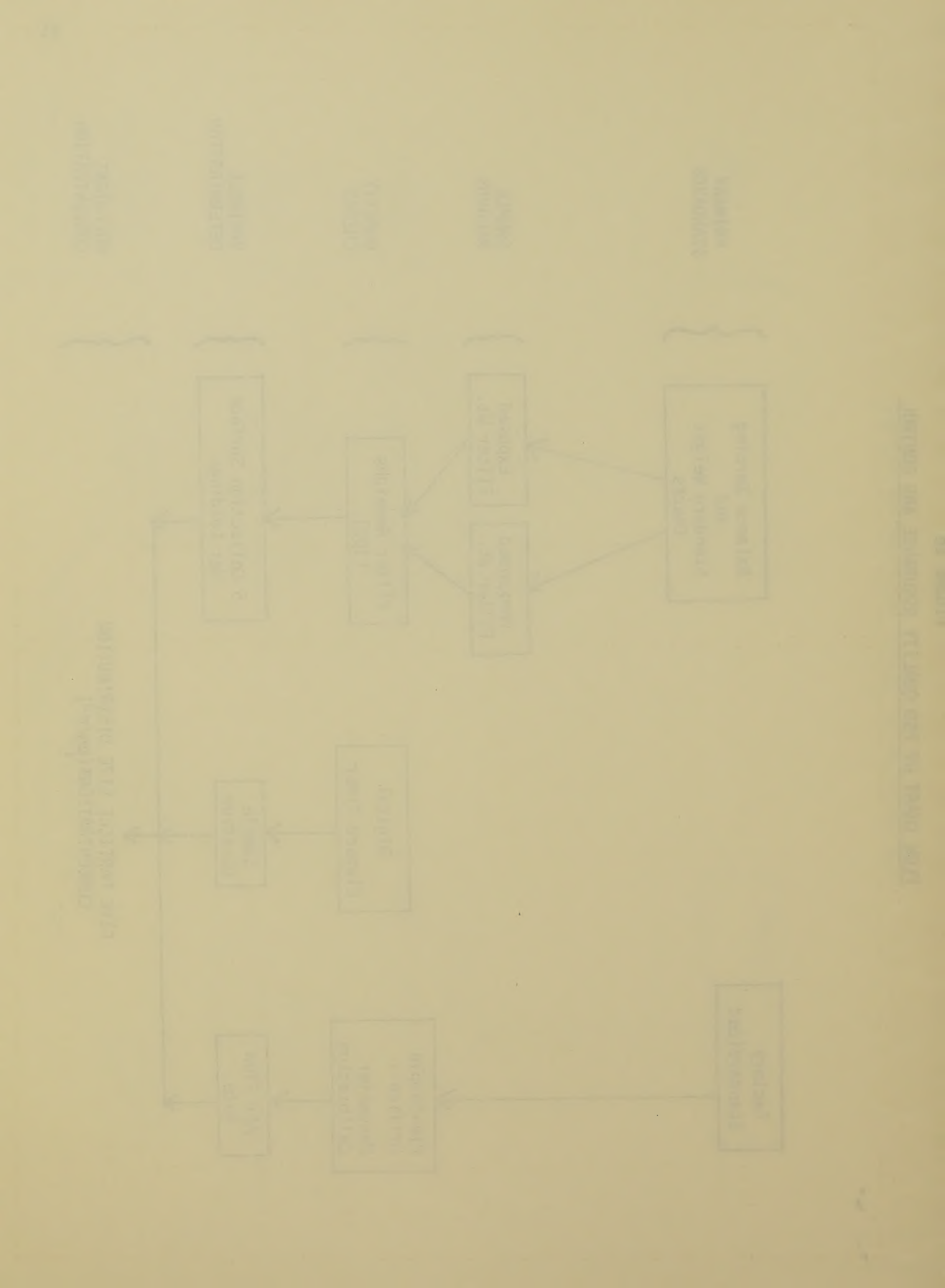


FIGURE 3a

TSP CONCENTRATION VS. SAMPLE AIR FLOW

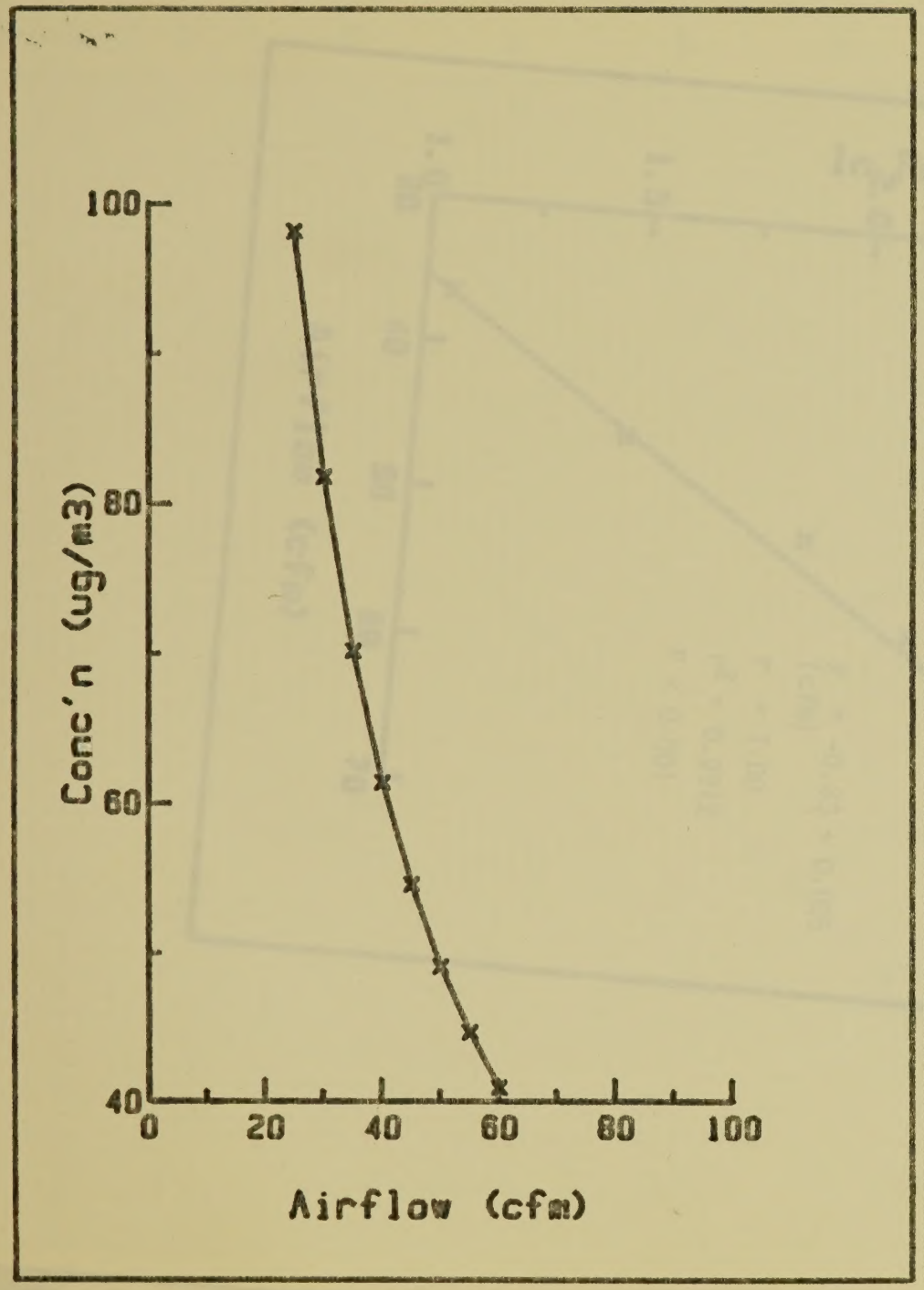
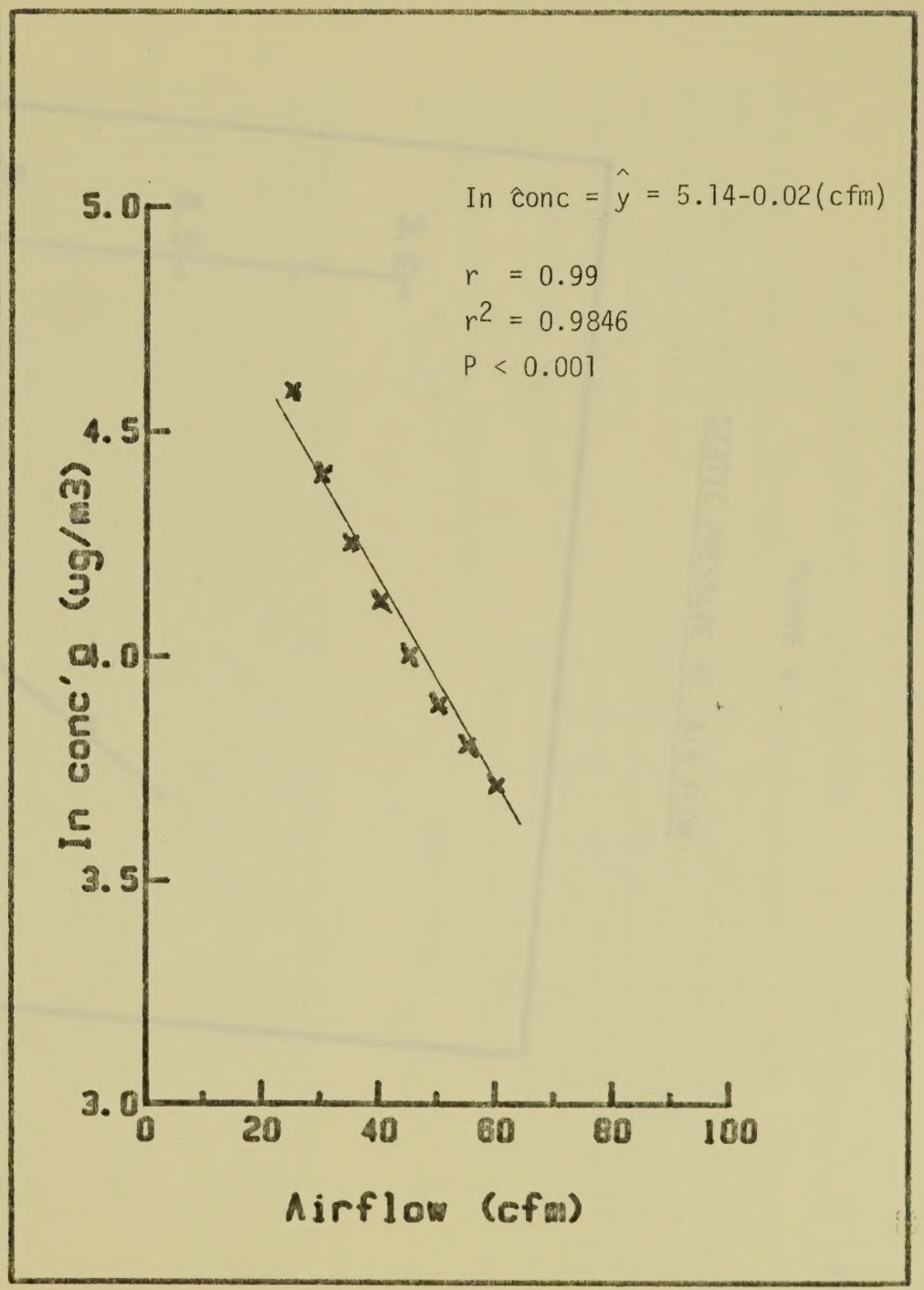
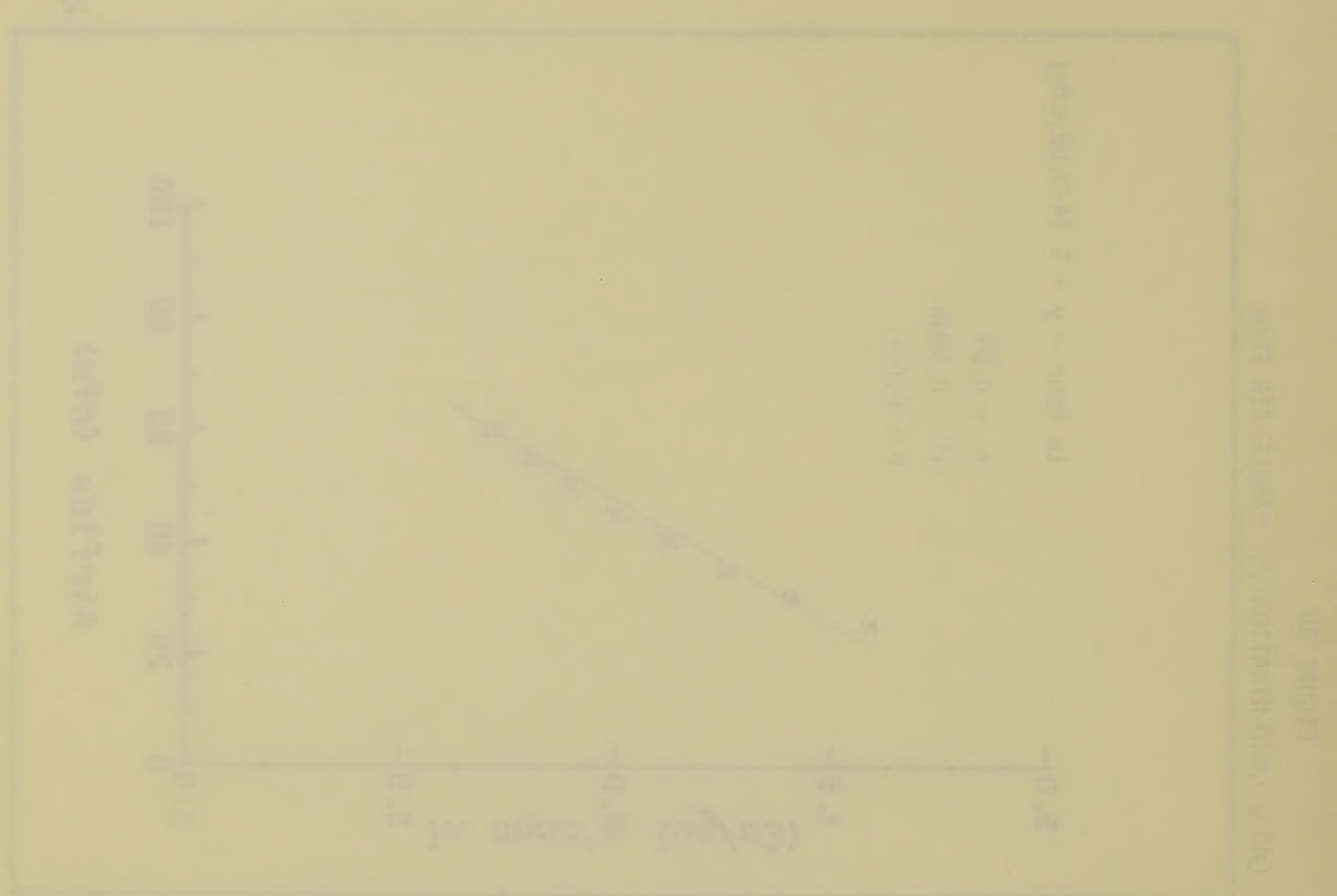


FIGURE 3b

LOG e CONCENTRATION VS. SAMPLE AIR FLOW





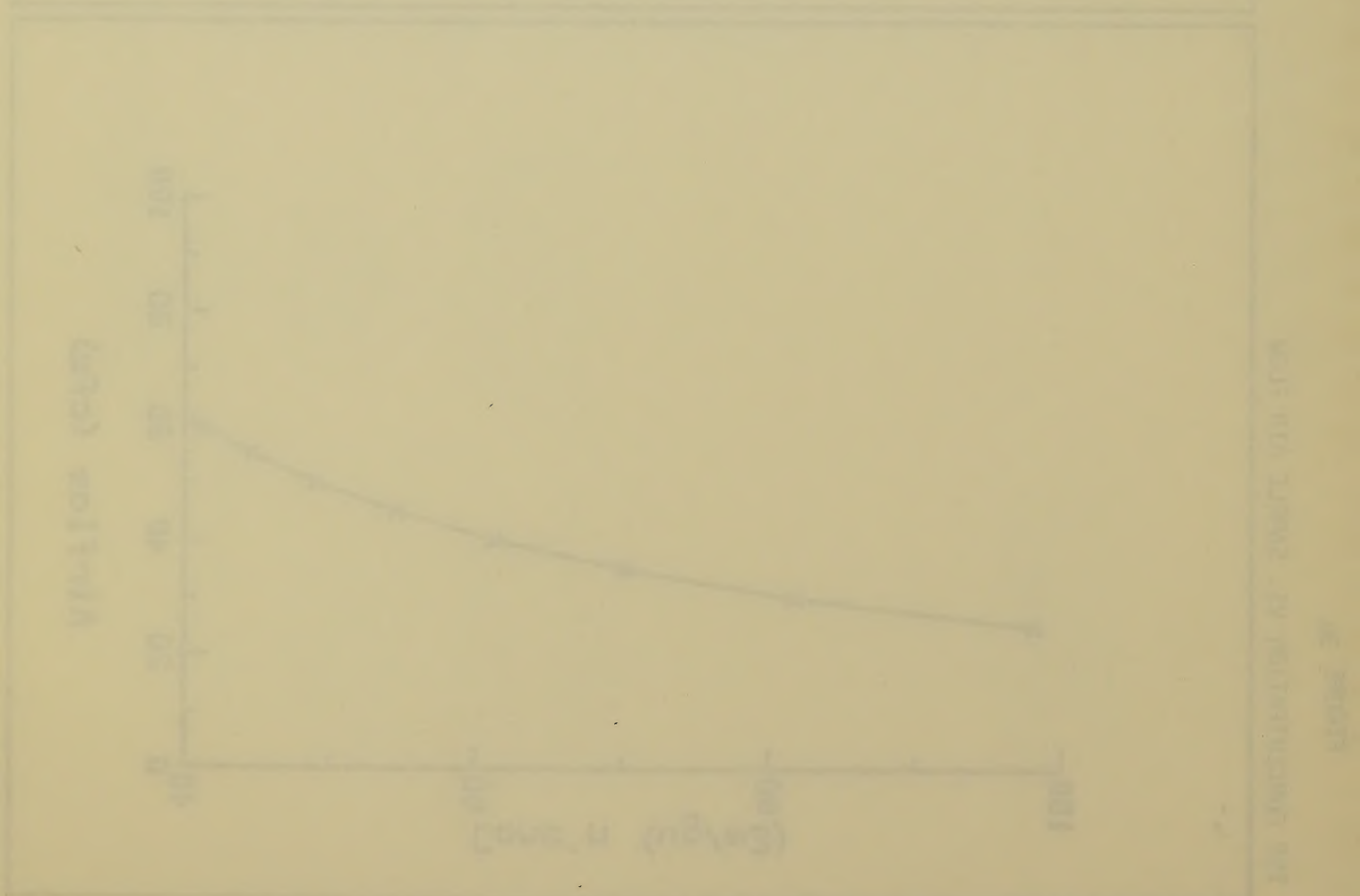


FIGURE 4

STATIC PRESSURE VS. AIR FLOW

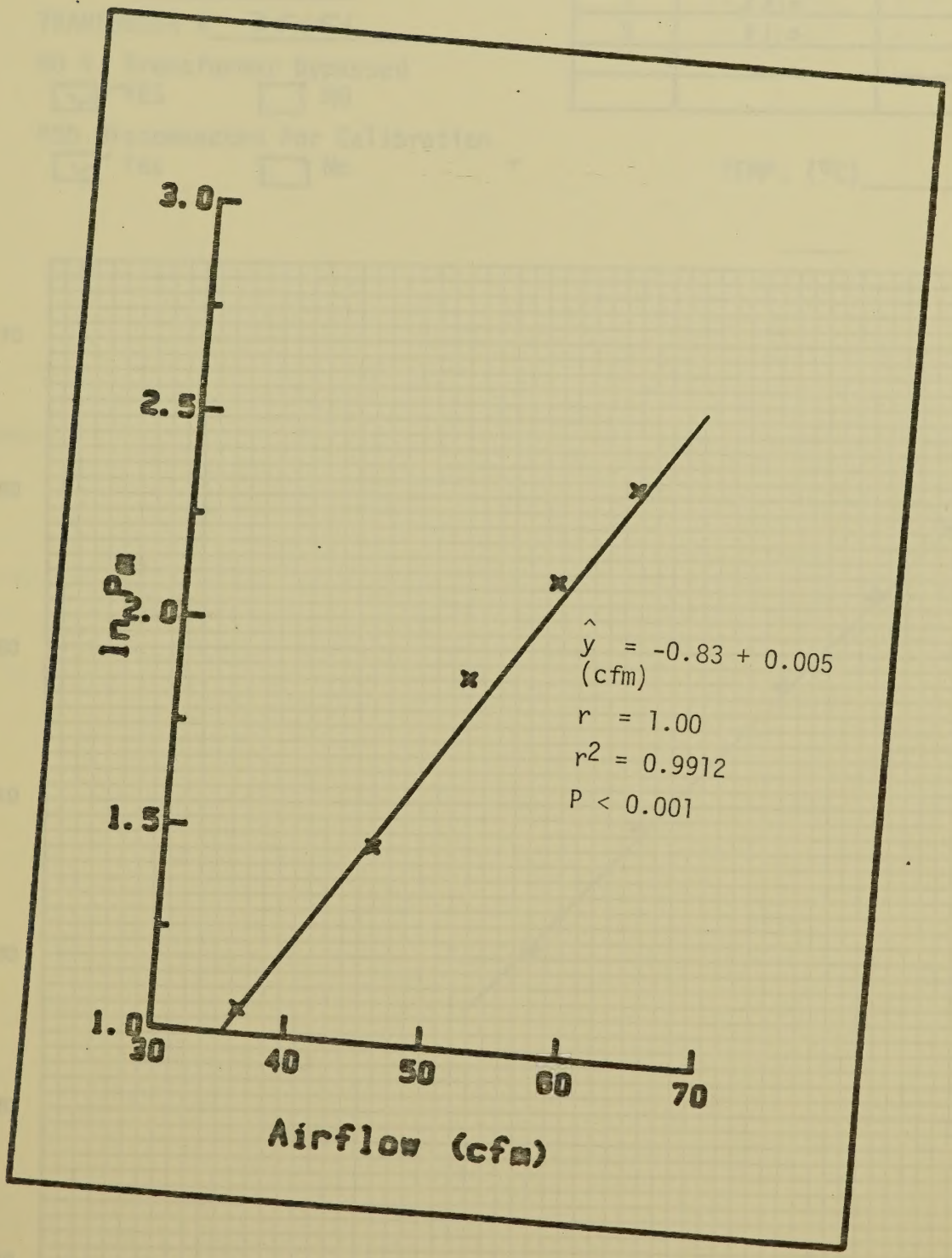


FIGURE 5

CALIBRATION DATA SHEET

HIGH VOLUME AIR SAMPLER CALIBRATION

Technician B

SITE NAME Red Hill Creek

DATE Feb. 1, 1979

UNIT # 1978-06A

MOTOR # 13026

TRANSDUCER # 35651

90 V. Transformer Bypassed

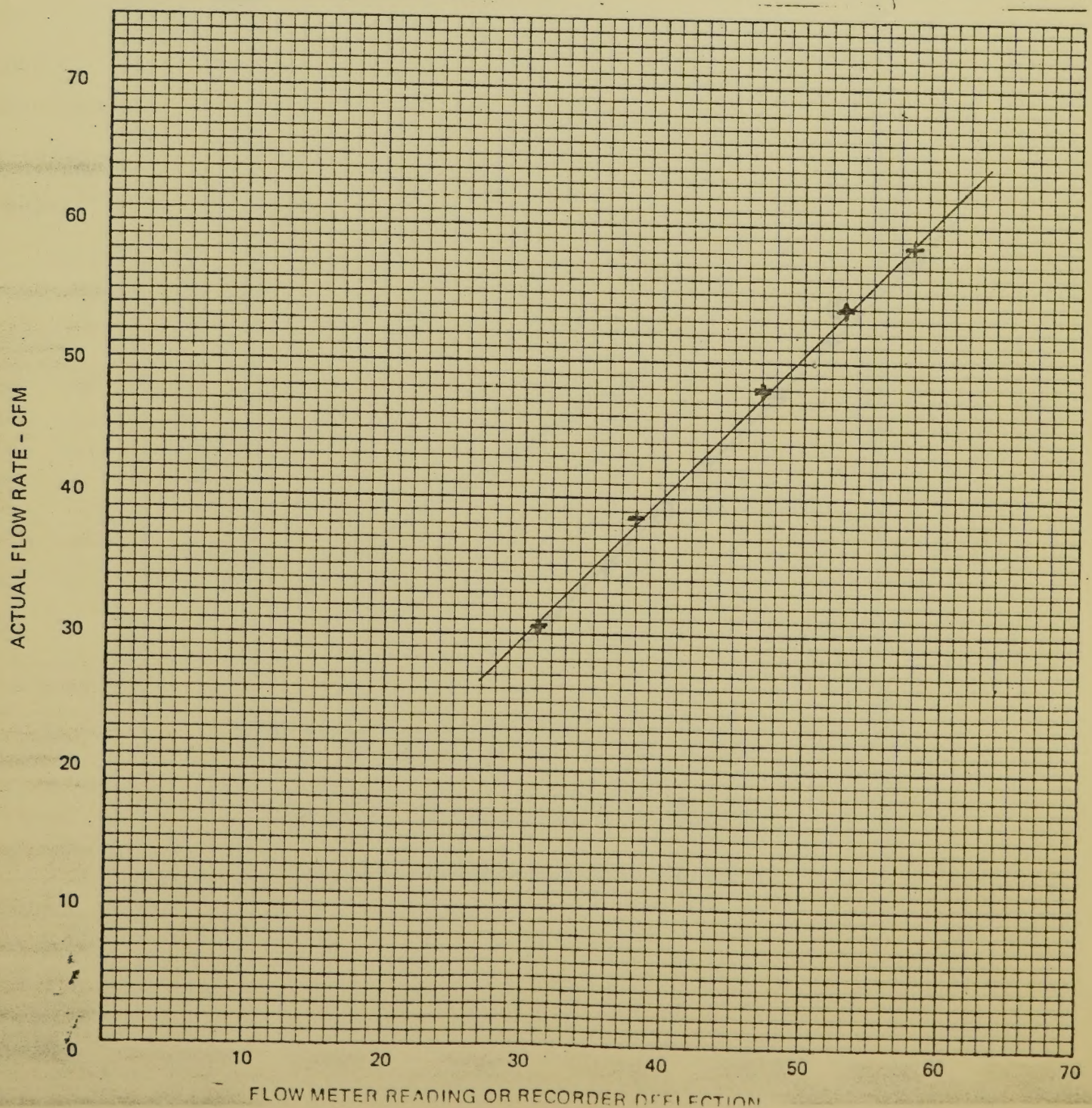
☑ YES ☐ NO

PSD Disconnected For Calibration

☑ Yes ☐ No

Plate	Indicated	True "H_2O	Actual cfm
18	58.0	11.0	58.5
13	53.0	9.3	54.0
10	47.0	7.4	48.0
7	38.0	5.0	39.5
5	31.0	3.0	30.5

TEMP. (°C)_____ Pb (inHg.)_____



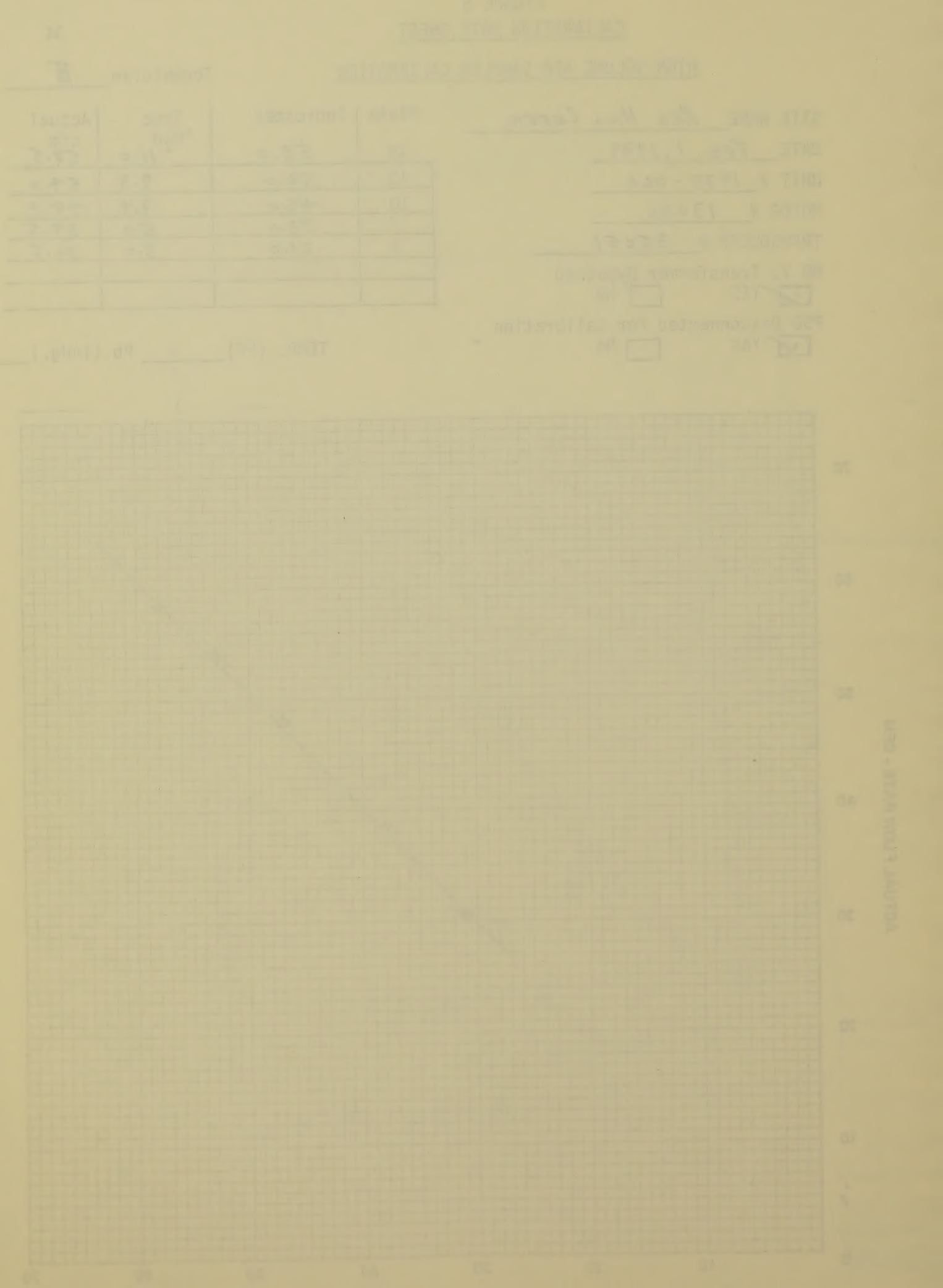


FIGURE 6

CALIBRATION DATA SHEET

HIGH VOLUME AIR SAMPLER CALIBRATION

Technician ~~B~~

SITE NAME *RED HILL CREEK*

DATE *JAN. 30, 1979*

UNIT # *1978-07*

MOTOR # *13026*

TRANSDUCER # *35651*

90 V. Transformer Bypassed

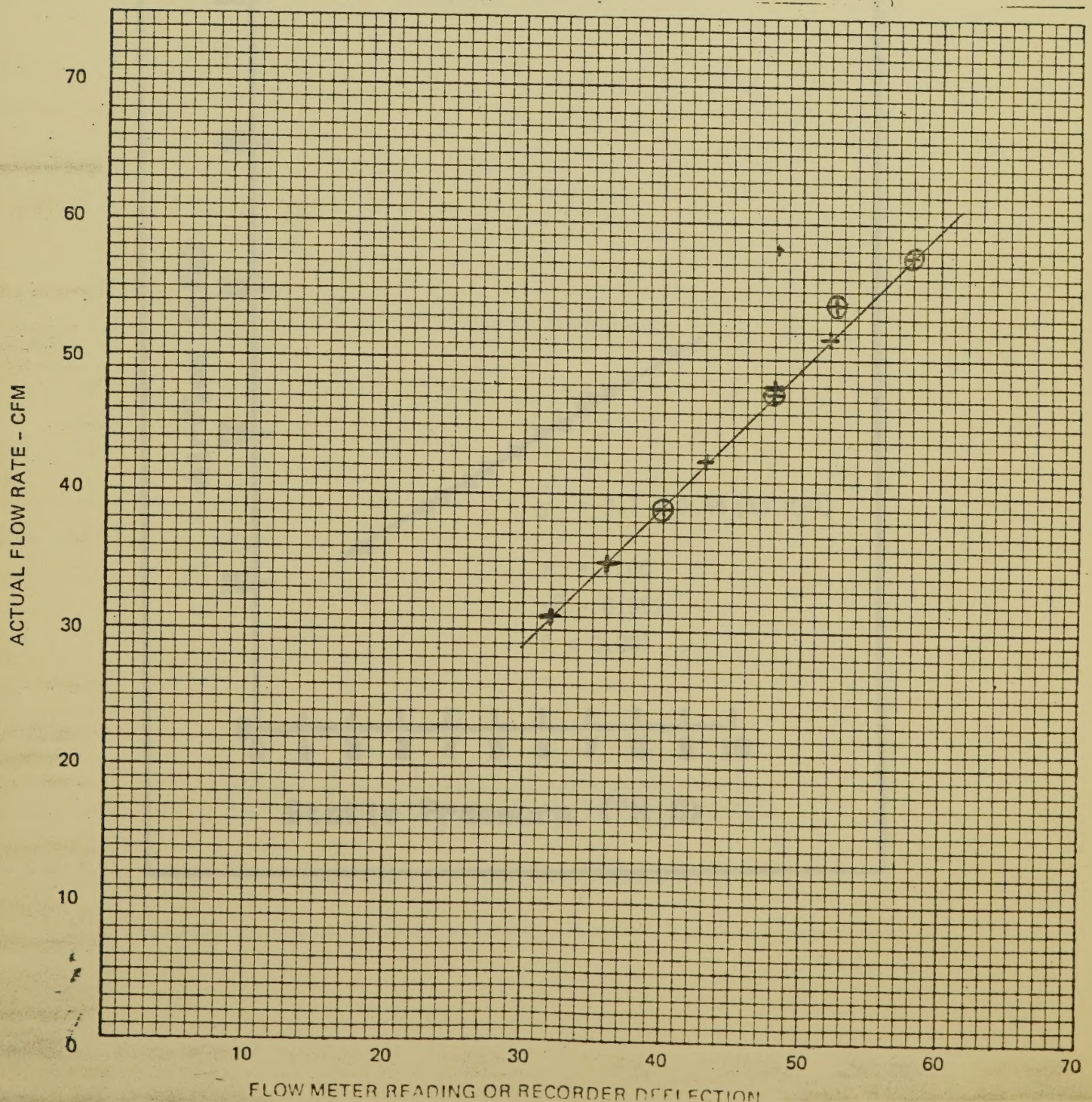
☐ YES ☐ NO

PSD Disconnected For Calibration

☐ Yes ☐ No

Plate	Indicated 90 V	Indicated 115 V	True "H_2O 115 V		Actual cfm 115 V	
18	52	58	8.4	10.6	51.5	57.5
13	48	54	7.3	8.7	48.0	52.5
10	43	48	5.8	7.2	42.5	47.5
7	36	40	3.9	4.8	35.0	39.0
5	30	32	2.5	3.0	N/A	31.0

TEMP. (°C)_____ Pb (inHg.)_____



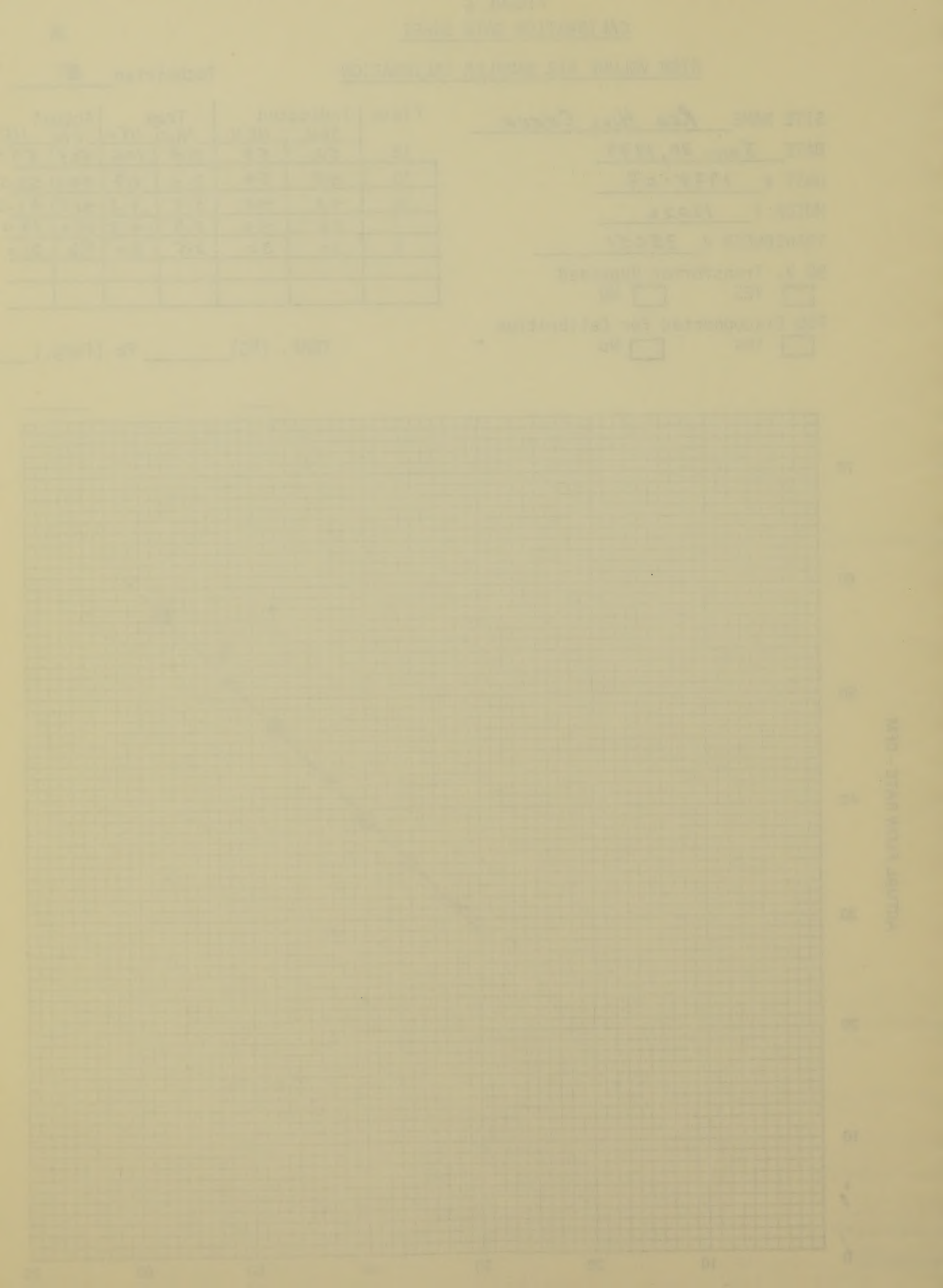
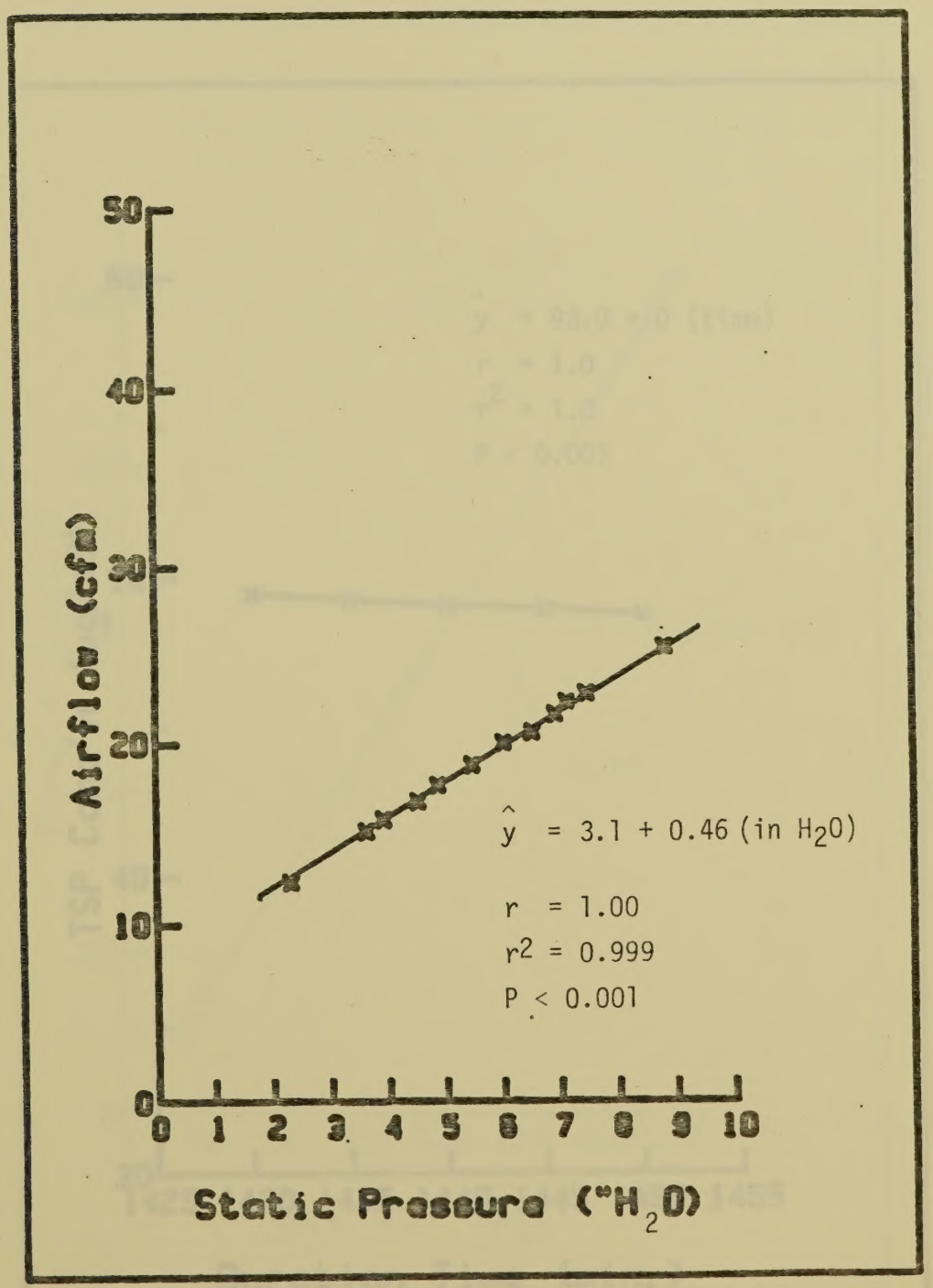


FIGURE 7

RELATIONSHIP OF PSD FLOW RATE TO STATIC PRESSURE DROP



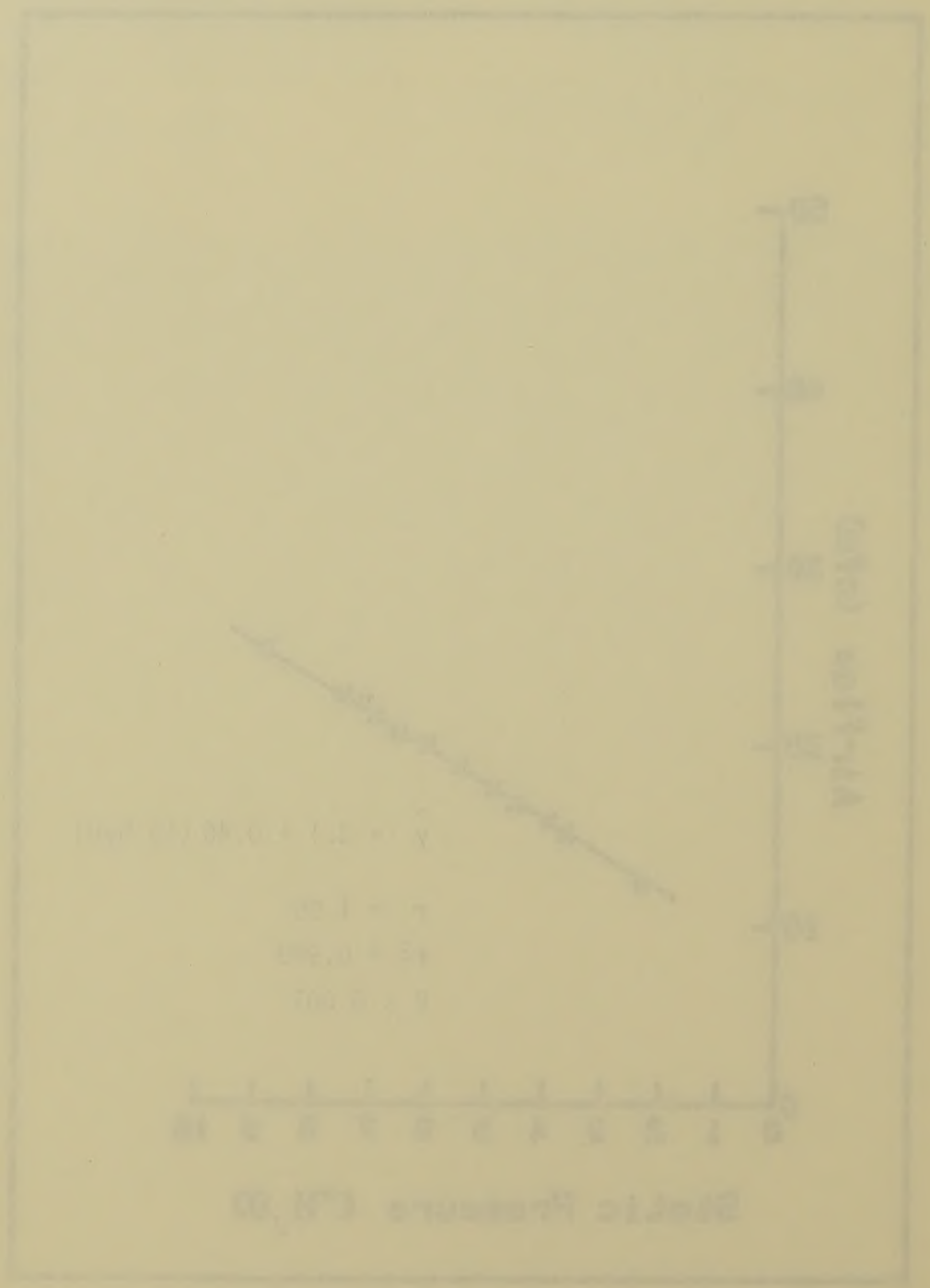


FIGURE 8

TSP CONCENTRATION VS. TIME MEASUREMENT PRECISION

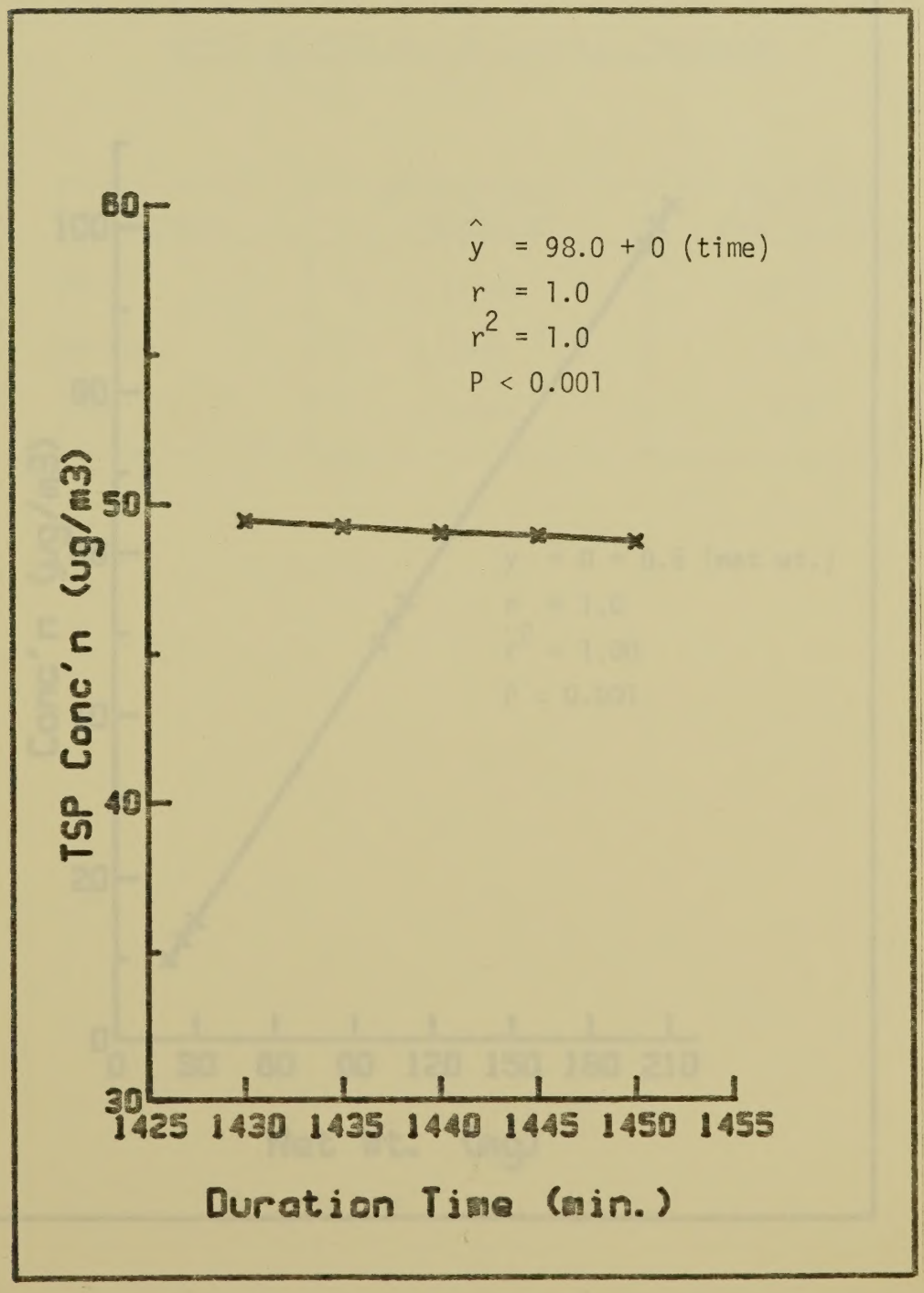
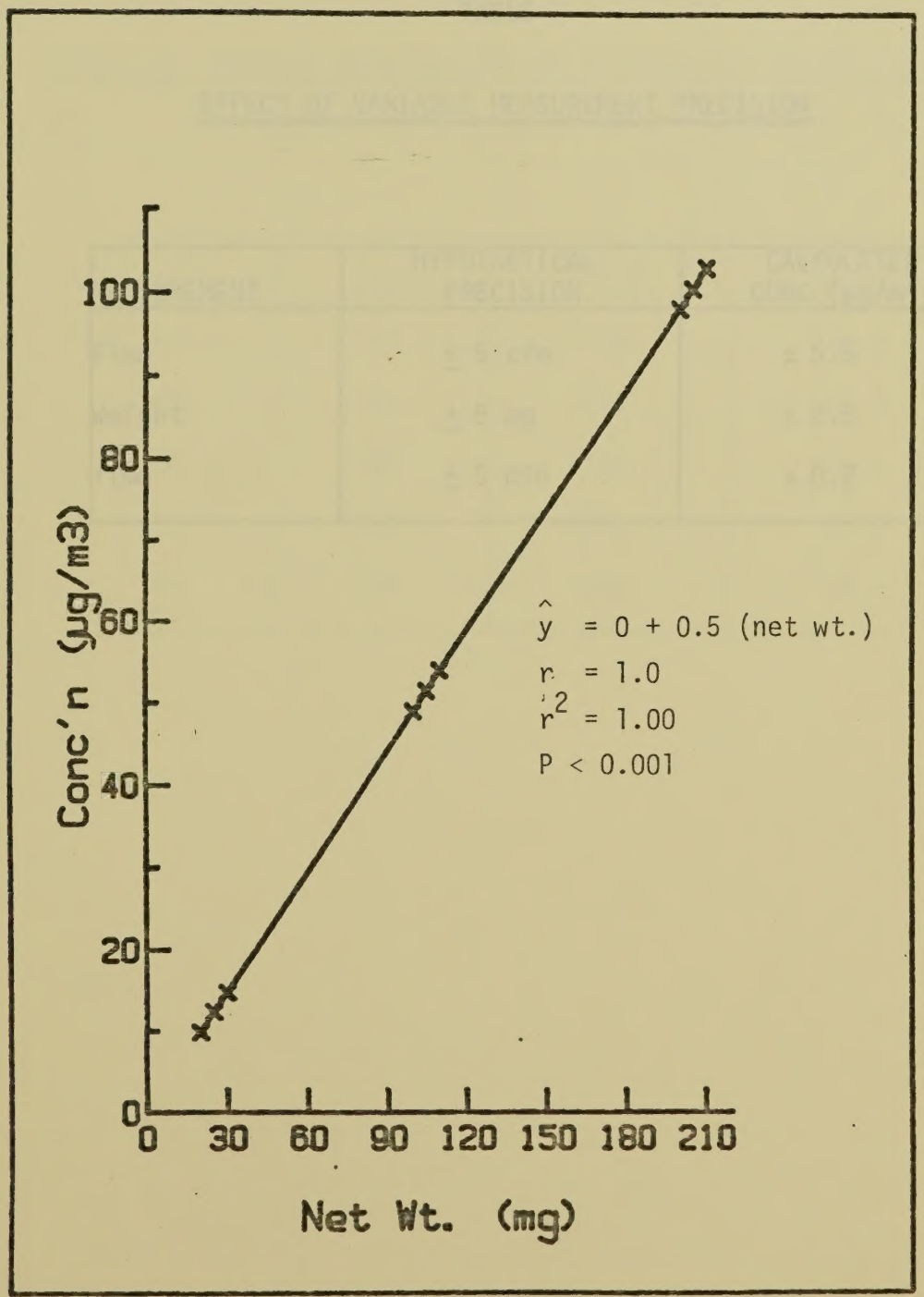


FIGURE 9

TSP CONCENTRATION VS. NET PARTICULATE LOADING



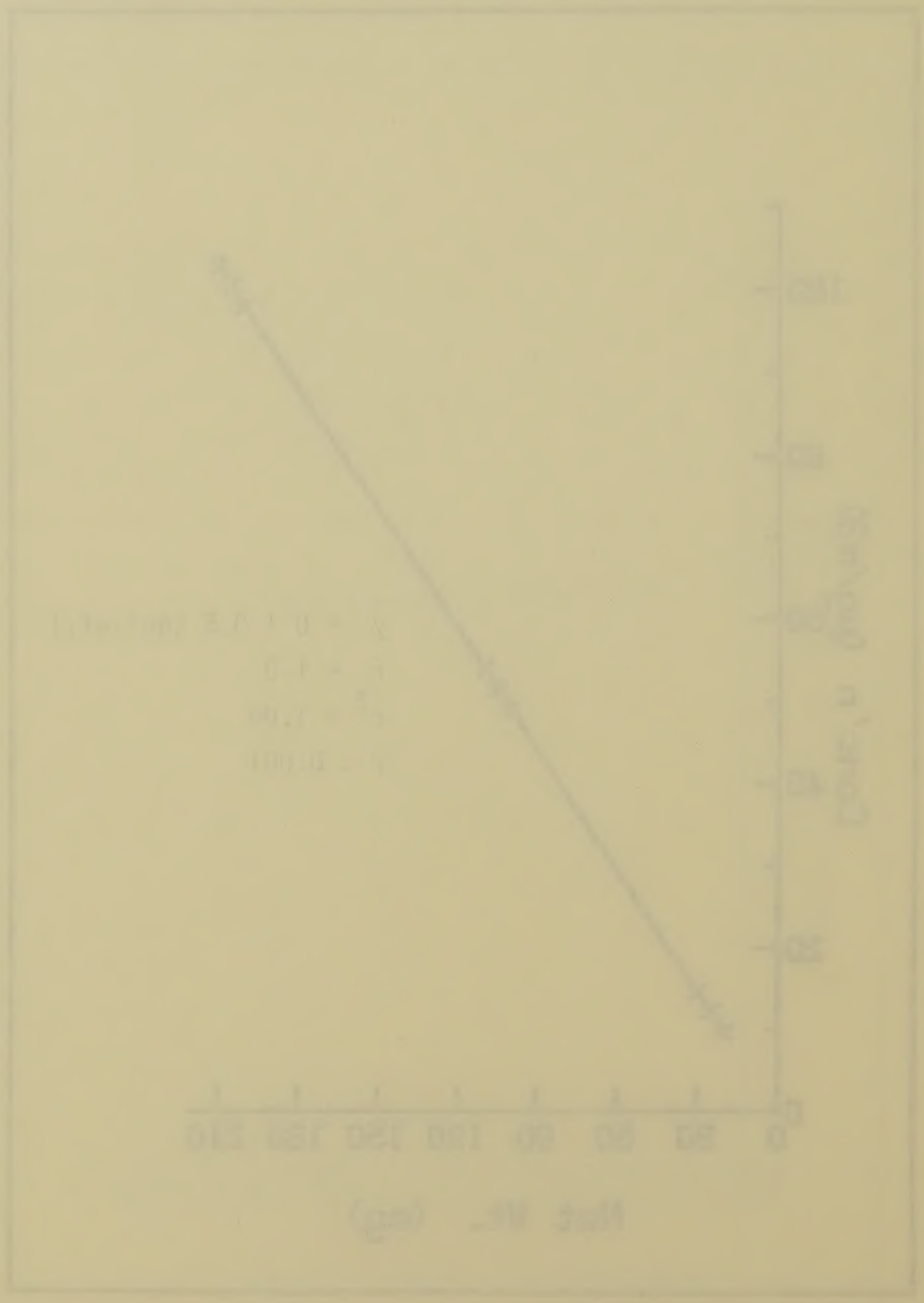


TABLE 1

EFFECT OF VARIABLE MEASUREMENT PRECISION

MEASUREMENT	HYPOTHETICAL PRECISION	CALCULATED CONC ($\mu g/m^3$)
Flow	$\pm$ 5 cfm	$\pm$ 5.5
Weight	$\pm$ 5 mg	$\pm$ 2.5
Time	$\pm$ 5 min	$\pm$ 0.2

TABLE 2

EFFECT OF VARIABLE COMBINATIONS ON PARTICULATE CONCENTRATIONS

FLOW (cfm)	WT. (mg)	T (min)	CONC^{n} ($\mu g/m^3$)
50	100	1440	49.0
50	105	1445	51.3
55	100	1445	44.4
55	105	1440	46.8
55	105	1445	46.7

TABLE 3

EFFECT OF FLOW MEASUREMENT PRECISION

FLOW (ft^3/min)	WT (mg)	T (min)	CONC ($\mu g/m^3$)	DIFF. CONC ($\mu g/m^3$)
25	100	1440	98.1	
				16.4
30	100	1440	81.7	
				11.6
35	100	1440	70.1	
				8.8
40	100	1440	61.3	
				6.8
45	100	1440	54.5	
				5.5
50	100	1440	49.0	
				4.4
55	100	1440	44.6	
				3.7
60	100	1440	40.9	—

TABLE 4

CONCENTRATION VARIABLE TRANSFORMATION

FLOW (cfm)	CONC$_n$ ($\mu g/m^3$)	ℓn CONC$_n$
25	98.1	4.59
30	81.7	4.40
35	70.1	4.25
40	61.3	4.12
45	54.5	4.00
50	49.0	3.89
55	44.6	3.80
60	40.9	3.71

TABLE 5

REGRESSION ANOVA TABLE

SOURCE	df	SS	MS	F	P
REGRESSION	1	0.64	0.64	378.28	<0.001
RESIDUAL	6	0.01	0.00*		
TOTAL	7	0.65	0.09		

*Due to rounding, not actually zero.

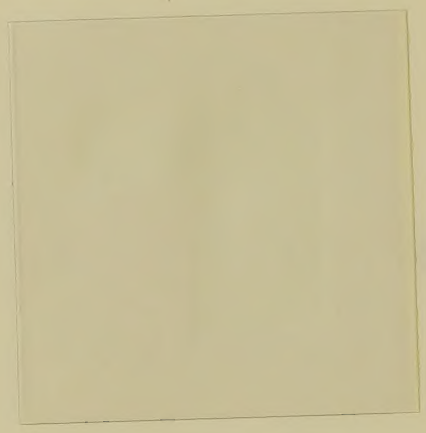


TABLE 6

TRANSFORMATION OF STATIC PRESSURE READINGS TO ACHIEVE LINEARITY

Pm ("H_2O)	Pm' (ℓn Pm)	F (TRUE CFM)
2.9	1.06	36.4
4.4	1.48	45.4
6.7	1.90	51.4
8.6	2.15	57.3
10.9	2.39	62.5

TABLE 7

REGRESSION ANOVA TABLE

SOURCE	df	SS	MS	F	P
REGRESSION	1	1.12	1.12	508.92	<0.001
RESIDUAL	3	0.01	0.00*		
TOTAL	4	1.13	0.28		

*Due to rounding, not actually zero.

TABLE 8

SUMMARY OF TSP CALIBRATION REGRESSIONS

SITE	CALIBRATION DATE	# OF PAIRS	SLOPE	S E	F	P	Y-INTER.	S E	F	P
ABERDEEN	JAN. '79	4	1.3	0.1	511.3	<0.005	-12.3	2.3	28.6	0.029
	AUG. '80	5	0.9	0.0	1024.7	<0.001	14.9	1.2	154.2	<0.001
	JULY '81	5	0.9	0.0	1091.3	<0.001	12.4	1.2	106.8	<0.005
ALBERTON	AUG. '79	4	1.0	0.0	425.1	<0.005	-1.2	2.1	0.3	0.637
	SEPT. '80	5	0.9	0.0	2709.9	<0.001	10.5	0.6	306.3	<0.001
	OCT. '80	5	0.8	0.1	241.4	<0.001	22.3	1.8	153.5	<0.001
	FEB. '81	5	0.8	0.1	119.5	<0.005	21.6	2.4	81.0	<0.005
	FEB. '82	5	0.7	0.0	366.3	<0.001	26.1	1.2	473.0	<0.001
BARTON & SANFORD	JUNE '82	4	0.9	0.1	60.0	0.01	13.9	5.2	7.1	0.117
BISHOPSGATE	JULY '79	4	1.3	0.0	961.0	<0.001	-8.7	1.7	26.2	0.033
	AUG. '80	4	1.1	0.1	95.4	0.008	4.1	4.5	0.8	0.533
	OCT. '80	5	1.0	0.0	1092.9	<0.001	9.4	1.3	52.3	<0.005
	AUG. '81	5	1.5	0.2	71.2	<0.005	-15.9	6.9	5.3	0.104
	NOV. '81	5	0.9	0.0	559.0	<0.001	11.2	1.8	38.7	0.007
CATHEDRAL	APR. '79	5	1.0	0.0	1621.4	<0.001	2.6	1.1	5.6	0.098
	JULY '80	5	0.9	0.0	459.2	<0.001	15.7	1.8	76.1	<0.005
	FEB. '82	5	0.8	0.1	97.1	<0.005	19.4	3.7	27.5	0.012
DUNDURN	JAN. '79	4	1.0	0.0	730.6	<0.005	6.4	1.2	28.4	0.030
	JULY '80	4	0.8	0.0	6555.5	<0.001	14.4	0.5	829.4	<0.001
	JULY '81	5	0.8	0.0	380.0	<0.001	15.8	1.9	69.2	<0.005
	JULY '82	5	0.8	0.0	277.9	<0.001	15.9	2.3	47.8	>0.005
HIGHVIEW	JAN. '79(90V)	4	1.0	0.2	30.5	0.028	-0.8	8.1	0.01	0.927
	JAN. '79(115V)	5	1.1	0.0	1408.6	<0.001	-5.0	1.4	12.8	0.036
	JULY '80	5	1.0	0.1	138.3	<0.005	6.9	3.6	3.7	0.150
	SEPT. 81	5	0.9	0.0	371.4	<0.001	10.7	2.2	23.7	0.015
McELROY	JAN. '79	4	1.2	0.0	905.1	<0.001	-7.9	1.5	27.7	0.031
	JULY '80	5	0.9	0.0	458.3	<0.001	10.6	2.0	28.1	0.012
	SEPT. 81	5	0.9	0.0	519.7	<0.001	9.2	2.0	21.2	0.017
M.O.E.	FEB. '79	5	1.0	0.0			1.0	0.0		
	AUG. '79	4	1.1	0.1	315.1	<0.005	-8.1	3.0	7.3	0.114
	NOV. '79	4	1.1	0.0	1568.0	<0.001	-6.4	1.4	20.9	0.042
	JULY '80	5	0.9	0.1	195.9	<0.001	9.5	3.1	9.4	0.053
	OCT. '81	5	0.9	0.0	586.0	<0.001	11.5	1.8	40.8	0.006

TABLE 8 CONT'd -2

SUMMARY OF TSP CALIBRATION REGRESSIONS

SITE	CALIBRATION DATE	# OF PAIRS	SLOPE	S E	F	P	Y-INTER.	S E	F	P
MT. ALBION	MAY 8 '81	4	0.5	0.1	42.5	0.019	39.6	2.7	215.1	<0.005
	MAY 22'81	5	0.9	0.1	264.5	<0.001	13.3	2.5	28.3	0.011
	FEB. '82	5	0.9	0.0	1356.2	<0.001	10.2	1.2	72.3	<0.005
MT. HOPE	AUG. '79	5	0.9	0.0	2299.0	<0.001	7.5	0.8	87.9	<0.005
	OCT. '80	5	0.7	0.0	600.9	<0.001	21.7	1.3	278.6	0.001
	JUL. '81	4	0.8	0.0	961.4	<0.001	17.9	2.2	66.2	0.005
NEW HOPE	JAN. '79(100V)	4	1.0	0.0	1261.0	<0.001	2.4	1.3	1.4	0.327
	JAN. '79(115V)	5	1.0	0.0	1971.4	<0.001	1.2	1.1	1.2	0.354
	FEB. '79	5	1.0	0.0	2080.4	<0.001	-1.3	1.1	1.4	0.322
	AUG. '80	5	1.0	0.2	42.9	0.006	6.4	6.4	1.0	0.393
	OCT. '81	5	0.9	0.1	305.7	<0.001	8.5	2.4	12.5	0.037
SAN DIEGO	FEB. '79	5	1.1	0.0	1280.5	<0.001	-2.6	1.3	4.0	0.139
	JUNE '79	5	1.0	0.0	2960.7	<0.001	2.9	0.8	13.1	0.034
	DEC. '79	4	1.5	0.1	153.7	<0.005	-28.3	5.9	23.0	0.038
	JULY '80	5	1.1	0.1	69.1	<0.005	1.1	5.5	0.04	0.847
	FEB. '82	5	0.9	0.1	245.2	<0.001	8.4	2.8	9.0	0.056
UPPER OTTAWA	JAN. '79	3	1.1	0.1	147.0	0.052	-3.0	3.7	0.7	0.555
	AUG. '80	5	0.8	0.1	166.0	<0.001	15.9	2.8	32.2	0.009
	FEB. '82	4	0.8	0.0	436.2	<0.005	17.5	1.7	106.0	0.007
	APRIL'82	5	0.9	0.1	54.8	<0.005	8.6	6.1	2.0	0.252
UPPER WENTWORTH	FEB. '79	5	1.0	0.0	9920.2	<0.001	-1.0	0.5	4.0	0.139
	AUG. '80	5	1.0	0.1	283.6	<0.001	8.5	2.6	10.7	0.045
	OCT. '81	5	0.8	0.0	475.6	<0.001	17.7	1.6	122.4	<0.005
WESTMOUNT	JUNE '79	4	1.2	0.1	280.8	<0.005	-2.1	2.5	0.7	0.508
	NOV. '79	5	1.2	0.0	653.7	<0.001	-2.4	1.9	1.6	0.296
	AUG. '80	5	1.0	0.1	222.6	<0.001	9.1	2.9	9.8	0.051
	SEPT.'81	5	1.0	0.1	143.3	<0.005	9.0	3.5	6.6	0.082
	MAY '82	5	0.9	0.0	691.7	<0.001	14.4	1.5	92.2	<0.005
WHITNEY	JAN. '79	5	1.1	0.0	2628.8	<0.001	-2.3	1.0	5.3	0.104
	AUG. '80	4	0.9	0.0	1120.8	<0.001	11.1	1.2	85.6	0.009
	JULY '81	5	0.9	0.0	588.4	<0.001	11.6	1.7	46.6	0.005

TABLE 8 CONT'd -3

SUMMARY OF TSP CALIBRATION REGRESSIONS

SITE	CALIBRATION DATE	#OF PAIRS	SLOPE	SE	F	P	Y - INTER.	SE	F	P
WOODWARD	AUG. '79	4	1.0	0.0	1420.1	<0.001	-0.6	1.2	0.25	0.664
	AUG. '80	5	1.0	0.1	144.9	<0.005	4.7	3.7	1.6	0.296
	FEB. '82	5	1.0	0.1	166.4	<0.001	7.6	3.3	5.3	0.104
n			66				66			
$\bar{y}$			0.976				6.3			
SD			0.158				10.0			
VAR			0.025				97.9			
RANGE			0.8				67.9			

TABLE 9

SUMMARY OF INDIVIDUAL TSP CALIBRATION ANOVAs

SITE	CALIBRATION DATE	SOURCE OF VARIATION: PLATES F	PLATES P	OBSERVED VS. ACTUAL F	OBSERVED VS. ACTUAL P	COEFFICIENT OF DETERMINATION
ABERDEEN	JAN. '79	49.2	<0.005	0.2	>0.1	0.9796
	AUG. '80	165.3	<0.001	132.3	<0.005	0.9950
	JULY '81	450.2	<0.001	432.4	<0.001	0.9983
ALBERTON	AUG. '79	1041.0	<0.001	61.0	<0.005	0.9987
	SEPT.'80	656.8	<0.001	410.0	<0.001	0.9987
	OCT. '80	63.5	<0.005	117.0	<0.005	0.9894
	FEB. '81	49.0	<0.005	105.8	<0.005	0.9869
	FEB. '82	23.7	0.007	52.0	<0.005	0.9736
BISHOPSGATE	JULY '79	55.7	<0.005	12.4	0.037	0.9832
	AUG. '80	114.6	<0.005	212.6	<0.001	0.9946
	OCT. '80	1060.0	<0.001	990.0	<0.001	0.9994
	AUG. '81	19.7	0.009	1.2	>0.1	0.9525
	NOV. '81	159.8	<0.001	39.1	<0.005	0.9943
CATHEDRAL	APR. '79	2700.0	<0.001	156.0	<0.001	0.9995
	JULY '80	152.3	<0.001	159.4	<0.001	0.9949
	FEB. '82	68.7	<0.005	95.3	<0.005	0.9894
DUNDURN	JAN. '79	1025.0	<0.001	451.0	<0.001	0.9989
	JULY '80	91.2	<0.005	19.5	0.020	0.9990
	JULY '81	81.9	<0.005	44.2	<0.005	0.9894
	JULY '82	N/A				
HIGHVIEW	JAN. '79	318.3	<0.001	00.0		0.9969
	JULY '80	188.3	<0.001	90.8	<0.005	0.9953
	SEPT.'81	221.2	<0.001	84.6	<0.005	0.9960
McELROY	JAN. '79	111.0	<0.005	0.13	>0.1	0.9911
	JULY '80	173.0	<0.001	36.1	0.005	0.9945
	SEPT.'81	225.9	<0.001	38.2	<0.005	0.9959
M.O.E.	FEB. '79	RESIDUAL MS = 0.0				
	AUG. '79	362.7	<0.001	201.7	<0.001	0.9982
	NOV. '79	657.5	<0.001	82.5	<0.005	0.9985
	JULY '80	129.8	<0.001	20.1	0.012	0.9929
	OCT. '81	198.8	<0.001	79.1	<0.005	0.9955
MT. ALBION	MAY 8'81	7.2	0.070	27.3	0.012	0.9420
	MAY22'81	169.4	<0.001	117.6	<0.005	0.9949
	FEB. '82	754.0	<0.001	456.3	<0.001	0.9988
MT. HOPE	AUG. '79	211.2	<0.001	14.1	0.021	0.9956
	OCT. '80	40.8	<0.005	40.9	<0.005	0.9807
	JULY '81	59.1	<0.005	43.0	<0.005	0.9860
	JULY '82	N/A				
RED HILL	JAN. '79	2231.0	<0.001	20.0	0.012	0.9997
	FEB. '79	1251.5	<0.001	3.0	>0.1	0.9993
	AUG. '80	58.0	<0.005	29.0	0.007	0.9852
	OCT. '81	330.7	<0.001	165.3	<0.001	0.9973
SAN DIEGO	FEB. '79	266.3	<0.001	13.4	0.022	0.9965
	JUNE '79	2638.0	<0.001	110.0	<0.005	0.9997
	DEC. '79	21.8	0.015	4.1	>0.1	0.9587
	JULY '80	72.3	<0.005	19.9	0.012	0.9874
	FEB. '82	235.1	<0.001	57.6	<0.005	0.9959
UP. OTTAWA	JAN. '79	141.0	0.006	41.0	0.02	0.9954
	AUG. '80	60.8	<0.005	26.6	0.008	0.9856
	FEB. '82	57.9	<0.005	36.3	0.008	0.9861
	APR. '82	71.7	<0.005	17.8	0.015	0.9871

. . . cont'd

SUMMARY OF INDIVIDUAL TSP CALIBRATION ANOVAs

SITE	CALIBRATION DATE	SOURCE OF VARIATION: PLATES F	PLATES P	OBSERVED VS. ACT. F	OBSERVED VS. ACT. P	COEFFICIENT OF DETERMINATION
UPPER WENTWORTH	FEB. '79	1236.0	<0.001	18.0	0.014	0.9994
	AUG. '80	337.7	<0.001	155.6	<0.001	0.9974
	OCT. '81	54.0	<0.005	28.5	0.007	0.9840
WESTMOUNT	JUNE '79	131.0	<0.005	40.8	0.007	0.9935
	NOV. '79	119.6	<0.005	33.8	0.006	0.9922
	AUG. '80	317.8	<0.001	432.4	<0.001	0.9975
	SEPT.'81	192.6	<0.001	156.6	<0.001	0.9957
	MAY '82	283.6	<0.001	378.9	<0.001	0.9973
WHITNEY	JAN. '79	372.7	<0.001	16.7	0.016	0.9976
	AUG. '80	364.2	<0.001	210.2	<0.001	0.9979
	JULY '81	263.2	<0.001	140.0	<0.005	0.9967
WOODWARD	AUG. '79		RESIDUAL MS = 0.0			
	AUG. '80	184.8	<0.001	50.0	<0.005	0.9952
	FEB. '82	199.5	<0.001	78.4	<0.005	0.9957
					n =	61
					y =	0.9915
					S D =	0.0110
					VAR. =	0.00011

TABLE 10

INTER-YEAR CALIBRATED FLOWS BY SAMPLER

YEAR / SAMPLER	CALIBRATED FLOWS (cfm) 1981	1980	Δ CFM (1981-1980)
1	42.5	41.0	1.5
2	32.0	37.0	-5.0
3	48.0	49.0	-1.0
4	47.0	47.0	0.0
5	46.0	46.0	0.0
6	44.0	44.0	0.0
7	46.0	46.0	0.0
8	50.0	49.0	1.0
9	58.0	59.0	-1.0
10	47.0	46.0	1.0
11	50.0	47.0	3.0
12	47.0	45.0	2.0
13	48.0	52.0	-4.0
14	47.0	45.0	2.0
15	64.0	61.0	3.0
16	42.0	42.0	0.0
17	44.0	46.0	-2.0
$\bar{y}$	47.2	47.2	0.029
S D	6.7	5.9	2.197

TABLE 11

TWO-WAY ANALYSIS OF VARIANCE BETWEEN SAMPLERS AND YEARS

SOURCE	df	SS	MS	F	P
SAMPLERS	16	1235.4	77.2	32.2	<0.001
YEARS	1	0.0*	0.0*	0.0*	>0.999
RESIDUAL	16	38.6	2.4		
TOTAL	33	1274.0			

*Due to rounding, not actually zero.

TABLE 12

TSP CALIBRATION SUMMARY BY SITE AND DATE

SITE	CALIBRATION DATES						
NAME	FIRST	SECOND	THIRD	FOURTH	FIFTH	# MATCHED SETS	
ABERDEEN	JAN. '79 M-13023 T-35668	AUG. '80 M-13030 T-35682	JULY '81 M-13030 T-35682				2
ALBERTON	AUG. '79 M-10891 T-29455	SEPT. '80 M-11005 T-28273	OCT. '80 M-11005 T-28273	FEB. '81 M-11005 T-28273	FEB. '82 M-1105 T-28273		4
BISHOPSGATE	JULY '79 M-12893 T-27575	AUG. '80 M-12893 T-27575	OCT. '80 M-10891 T-27575	AUG. '81 M-10891 T-27575	NOV. '81 M-10891 T-28867		2X2
CATHEDRAL	APRIL '79 M-10530 T-34379	JULY '80 M-10530 T-34379	FEB. '82 M-10530 T-34379				3
DUNDURN	JAN. '79 M-13030 T-35682	JULY '80 M-13023 T-35668	JULY '81 M-13023 T-35668	JULY 13/82 M-13023 T-35668			3
HIGHVIEW	JAN. '79 M-13025 T-35653	JULY '80 M-13025 T-35653	SEPT. '81 M-13025 T-35653				3
McELROY	JAN. '79 M-13024 T-35679	JULY '80 M-13024 T-35679	SEPT. '81 M-11903 T-35679				2
M.O.E.	AUG. '79 M-11011 T-28867	FEB. '79 M-13032 T-34364	NOV. '79 M- ? T-34364	JULY '80 M-11011 T-34364	OCT. '81 M-11011? T-34364		?
MT. ALBION		MAY 8'81 M-13032 T-34013	MAY 22'81 M-13032 T-34013?	FEB. '82 M-13032 T-34013			3
MOUNT HOPE	AUG. '79 M-10529 T-29610	OCT. '80 M-10529 T-29610	JULY '81 M-10529 T-29610	JULY '82 M-10529 T-29610			4
RED HILL	JAN. '79 M-13026 T-35651	FEB. '79 M-13026 T-35651	AUG. '80 M-13026 T-35651	OCT. '81 M-13026 T-35651			4
SAN DIEGO	FEB. '79 M-13034 T-34367	JUNE '79 M-34013 T-12897	DEC. '79 M-12897 T-34367	JULY '80 M-12897 T-34367	FEB. '82 M-12897 T-34367		3
UPPER OTTAWA	JAN. '79 M-13028 T-35678	AUG. '80 M-13028? T-35678		FEB. '82 M-13028 T-35678	APRIL '82 M-16293 T-35678		3
UPPER WENTWORTH	FEB. '79 M-11903 T-35848	AUG. '80 M-11903 T-35848	OCT. '81 M-13024 T-35848				2
WESTMOUNT	JUNE '79 M-11014 T- ?	NOV. '79 M-11014 T-25899	AUG. '80 M-11014 T-25899	SEPT. '81 M-11014 T-25899	MAY '82 M-11014 T-25899		5
WHITNEY	JAN. '79 M-13027 T-35683	AUG. '80 M-13027 T-35683	JULY '81 M-13027 T-35683				3
WOODWARD	AUG. '79 M-11004 T-28333	AUG. '80 M-11004 T-28333		FEB. '82 M-11004 T-28333			3
BARTON & SANFORD III	JUNE '82 M-13028 T-27956						

TABLE 13

SUMMARY OF INTER-YEAR CALIBRATION ANOVA's

SITE	CALIBRATION DATES		"F"		"P"		MATCHED	NEW BRUSHES
	CAL. 1	CAL.2	INDICATED VS. ACTUAL	CAL. 1 VS. CAL. 2	INDICATED VS. ACTUAL	CAL. 1 VS. CAL. 2		
ABERDEEN	AUG. '80	JAN. '79	28.9	177.9	<0.001	<0.001	NO	-
	JULY '81	AUG. '80	433.2	<0.1	<0.001	>0.7	YES	NO
ALBERTON	SEPT. '80	AUG. '79	110.2	35.1	<0.001	<0.001	NO	-
	OCT. '80	SEPT. '80	238.2	6.4	<0.001	0.025	YES	YES
	FEB. '81	OCT. '80	244.3	0.7	<0.001	>0.5	YES	YES
	FEB. '82	FEB. '81	190.4	0.3	<0.001	>0.5	YES	NO
BISHOPSGATE	AUG. '80	JULY '79	142.8	29.2	<0.001	<0.001	YES	NO
	OCT. '80	AUG. '80	421.0	270.4	<0.001	<0.001	NO	-
	AUG. '81	OCT. '80	33.7	52.3	<0.001	<0.001	YES	YES
	NOV. '81	AUG. '81	13.6	91.8	<0.005	<0.001	NO	-
CATHEDRAL	JULY '80	APR. '79	213.1	30.9	<0.001	<0.001	NO	YES
	FEB. '82	JULY '80	294.1	0.8	<0.001	>0.5	NO	-
DUNDURN	JULY '80	JAN. '79	11.8	77.1	0.007	<0.001	NO	-
	JULY '81	JULY '80	20.2	3.1	<0.005	>0.1	YES	NO
HIGHVIEW	JULY '80	JAN. '79	71.8	0.4	<0.001	>0.5	YES	YES
	SEPT. '81	JULY '80	227.2	106.6	<0.001	<0.001	YES	YES
McELROY	JULY '80	JAN. '79	9.1	636.2	0.014	<0.001	YES	YES
	SEPT. '81	JULY '80	108.0	0.2	<0.001	>0.5	NO	YES
M.O.E.	AUG. '79	FEB. '79	33.9	6.7	<0.001	0.03	NO	-
	NOV. '79	FEB. '79	22.8	0.1	<0.005	>0.5	NO	-
	JULY '80	NOV. '79	0.6	93.3	>0.5	<0.001	NO	-
	OCT. '81	JULY '80	107.8	5.7	<0.001	0.033	NO	-
MT. ALBION	MAY 22/81	MAY 8/81	66.1	9.4	<0.001	0.013	NO	-
MT. HOPE	OCT. '80	AUG. '79	74.9	52.2	<0.001	<0.001	YES	YES
	JULY '81	OCT. '80	115.7	0.3	<0.001	>0.5	YES	NO
RED HILL	FEB. '79	JAN. '79	0.8	1.7	>0.5	>0.1	YES	NO
	AUG. '80	FEB. '79	23.9	2.5	<0.001	>0.1	YES	YES
	OCT. '81	AUG. '80	117.4	2.8	<0.001	>0.1	YES	NO
SAN DIEGO	FEB. '79	JUNE '79	45.7	13.1	<0.001	<0.005	NO	-
	DEC. '79	JUNE '79	1.0	5.9	>0.1	0.037	NO	-
	JULY '80	DEC. '79	1.0	0.3	>0.1	>0.5	YES	YES
	FEB. '82	JULY '80	78.4	106.8	<0.001	<0.001	YES	YES
UPPER OTTAWA	AUG. '80	JAN. '79	52.3	799.6	<0.001	<0.001	YES	YES
	FEB. '82	AUG. '80	77.7	16.7	<0.001	<0.005	YES	NO
	APR. '82	FEB. '82	69.2	2.7	<0.001	>0.1	NO	-
UPPER WENTWORTH	AUG. '80	FEB. '79	206.2	98.8	<0.001	<0.001	YES	NO
	OCT. '81	AUG. '80	126.5	0.1	<0.001	>0.5	NO	-
WESTMOUNT	NOV. '79	JUNE '79	42.3	183.0	<0.001	<0.001	YES	YES
	AUG. '80	NOV. '79	110.0	15.8	<0.001	<0.005	YES	NO
	SEPT. '81	AUG. '80	279.5	<0.1	<0.001	>0.7	YES	NO
	MAY '82	SEPT. '81	456.2	1.9	<0.001	>0.1	YES	YES
WHITNEY	AUG. '80	JAN. '79	64.3	8.7	<0.001	0.016	YES	YES
	JULY '81	AUG. '80	833.0	9.9	<0.001	0.012	YES	YES
WOODWARD	AUG. '80	AUG. '79	66.6	259.2	<0.001	<0.001	YES	YES
	FEB. '82	AUG. '80	155.6	1.7	<0.001	>0.1	YES	YES

TABLE 14

PRECISION OF FLOW CHART READING
(FLOWS IN CUBIC FEET PER MINUTE)

SAMPLE / OPERATOR	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	MEAN	S D
1	25	20	44	38	36	38	38	43	51	39	36	36	43	38	59	37	37	38.7	8.6
2	25	20	43	39	36	39	38	43	52	39	36	36	43	38	59	37	37	38.8	8.7
3	25	20	43	38	36	38	38	43	51	39	36	36	43	38	60	37	37	38.7	8.8
S D	0	0	0.5	0.6	0	0.6	0	0	0.6	0	0	0	0	0	0.6	0	0	0.14	

TABLE 15

[illegible] FOR SAMPLE FLOWS AND OBSERVERS

[illegible]	[illegible]	MS	F	P
[illegible]	[illegible].16	0.08	0.79	>0.1
[illegible]	[illegible].35	226.90	2283.29	<0.005
[illegible]	[illegible].18	0.10		
[illegible]	[illegible].69			

TABLE 16

PSD FLOW STABILITY ASSESSMENT DATA

SITE	STATIC PRESSURE (inches water)		Δ PRESSURE
	PRE-SAMPLE	POST-SAMPLE	PRE-POST
MOUNT HOPE	6.0	6.0	0.0
	6.0	6.4	-0.4
	6.0	5.7	0.3
	6.0	5.9	0.1
NORTH PARK	6.0	6.1	-0.1
	6.0	6.0	0.0
	6.0	5.8	0.2
	6.0	6.2	-0.2
SENECA	6.0	7.6	-1.6
	6.0	6.0	0.0
	6.0	5.8	0.2
	6.0	6.2	-0.2
RED HILL CREEK	6.0	6.9	-0.9
	6.0	6.1	-0.1
	6.0	6.3	-0.3
	6.0	6.1	-0.1
HIGHVIEW	6.0	6.0	0.0
	6.0	6.8	-0.8
	6.0	5.8	0.2
	6.0	5.9	0.1
WHITNEY II	6.0	5.8	0.2
	6.0	6.0	0.0
	6.0	5.7	0.3
	6.0	6.4	-0.4
SAN DIEGO	6.0	6.8	-0.8
	6.0	6.4	-0.4
	6.0	6.0	0.0
	6.0	5.8	0.2
UPPER OTTAWA	6.0	6.0	0.0
	6.0	7.5	-1.5
	6.0	6.0	0.0
n	31	31	31
$\bar{y}$	6.0	6.2	-0.2226
S D	0.0	0.48	0.498

TABLE 17

ANOVA TABLE OF PRE- AND POST-PSD SAMPLING STATIC PRESSURE DROPS

SOURCE	df	SS	MS	F	P
SAMPLES	30	3.4	0.1	1.0	0.5
READINGS	1	0.6	0.6	6.0	0.019
RESIDUAL	30	3.4	0.1		
TOTAL	61	7.4	0.1		

COEFFICIENT OF DETERMINATION = 0.5405

TABLE 18

RELATIONSHIP BETWEEN PSD FLOW RATE, LINE VOLTAGE AND STATIC PRESSURE DROP

LINE VOLTAGE (VAC)	STATIC PRESSURE ("H_2O)	AIR FLOW (cfm)
34	2.30	12.25
39	3.60	15.10
41	3.90	15.75
43	4.50	16.75
45	4.85	17.65
47	5.45	18.75
49	6.00	20.00
51	6.50	20.60
53	6.90	21.60
55	7.10	22.30
57	7.45	22.80
62	8.80	25.40

TABLE 19

PSD FLOW VS. STATIC PRESSURE DROP REGRESSION ANOVA TABLE

SOURCE	df	SS	MS	F	P
REGRESSION	1	154.60	154.60	7005.2	<0.001
RESIDUAL	10	0.22	0.02		
TOTAL	11	154.82	14.07		

TABLE 20

EFFECT OF FLOW PRECISION ON TOTAL PSD CONCENTRATION

FLOW (cfm)	NEW LOADING (mg)	SAMPLE TIME (min)	CONCENTRATION ($\mu g/m^3$)
19.77	40.0	1440	49.62
20.00	40.0	1440	49.06
20.23	40.0	1440	48.49
19.77	20.0	1440	24.81
20.00	20.0	1440	24.52
20.23	20.0	1440	24.25
19.77	5.0	1440	6.20
20.00	5.0	1440	6.13
20.23	5.0	1440	6.06

TABLE 21

EFFECT OF TIME MEASUREMENT PRECISION

T (min)	FLOW (cfm)	ΔWT (μg)	CONC^{n} (μg/m^3)	ΔCONC^{n} per 5 min
1430	50	100	49.4	
				0.2 μg/m^3
1435	50	100	49.2	
				0.2 μg/m^3
1440	50	100	49.0	
				0.1 μg/m^3
1445	50	100	48.9	
				0.2 μg/m^3
1450	50	100	48.7	

TABLE 22

TSP CONCENTRATION VS. TIME MEASUREMENT
REGRESSION ANALYSIS OF VARIANCE

SOURCE	df	SS	MS	F	P
REGRESSION	1	0.3	0.3	289.0	<0.001
RESIDUAL	3	0.0*	0.0*	-	
TOTAL	4	0.3	0.1		

*Due to rounding, not actually zero.

TABLE 23

TIME READING ANOVA DATA

	OBSERVER					
SAMPLES	A	B	C	n	$\bar{y}$	SD
1	1440	1440	1440	3	1440.0	0.0
2	1455	1455	1455	3	1455.0	0.0
3	1470	1470	1470	3	1470.0	0.0
4	1463	1460	1465	3	1462.7	2.5
5	1457	1455	1455	3	1455.7	1.2
6	1470	1465	1467	3	1467.3	2.5
7	1443	1445	1445	3	1444.3	1.2
8	1362	1355	1364	3	1360.3	4.7
9	1455	1455	1455	3	1455.0	0.0
10	1477	1480	1480	3	1479.0	1.7
11	1455	1455	1455	3	1455.0	0.0
12	0000	0000	0000	3	0.0	0.0
13	1445	1445	1445	3	1445.0	0.0
14	1433	1430	1433	3	1432.0	1.7
15	1430	1430	1430	3	1430.0	0.0
16	1403	1405	1403	3	1403.7	1.2
17	1440	1440	1440	3	1440.0	0.0
n	17	17	17	51	17	17
$\bar{y}$	1358.7	1357.9	1358.9	3	1358.5	1.0
SD	351.2	351.1	351.2	0	351.2	1.3

TABLE 24

TIME READING ANOVA TABLE

SOURCE	df	SS	MS	F	P
OBSERVERS	2	9.30	4.65	1.85	>0.1
SAMPLES	16	5919720.71	369982.54	146818.47	<0.001
RESIDUAL	32	80.70	2.52		
TOTAL	50	4919810.71			

$\sqrt{2.52} = 1.59$

TABLE 25

TSP CONCENTRATION VS. NET LOADING

REGRESSION ANOVA TABLE

SOURCE	df	SS	MS	F	P
REGRESSION	1	11771.0	11771.0	10289106.7	<0.001
RESIDUAL	7	0.0*	0.0*		
TOTAL	8	11771.0	11771.0		

* Due to rounding, not actually zero.

TABLE 26

EFFECT OF NET LOADING

NET WT. (mg)	FLOW (cfm)	T (min)	CONCn ($\mu g/m^3$)	Δ WT.	DIFFERENCE CONCn ($\mu g/m^3$)
20	50	1440	9.8		
25	50	1440	12.3	± 5 mg.	± 2.5
30	50	1440	14.7		
100	50	1440	49.0		
105	50	1440	51.5	± 5 mg.	± 2.5
110	50	1440	54.0		
200	50	1440	98.1		
205	50	1440	100.5	± 5 mg.	± 2.5
210	50	1440	103.0		

TABLE 27

ANALYSES OF BALANCE ZEROING AND STANDARD WEIGHTS

(ALL RESULTS EXPRESSED IN GRAMS)

PROCEDURE		n	MEAN	SD	MINIMUM	MAXIMUM	DIFFERENCE STATS. MEAN	SD	t	p
BALANCE	PRE	114	0.00000	0.00000	0.00000	0.00000	0.00001	0.00030	0.440	0.661
ZEROING	POST	114	0.00001	0.00030	-0.00140	0.00100				
STANDARD	PRE	114	1.00000	0.00027	0.99910	1.00150	-0.00002	0.00034	-0.046	0.963
WEIGHTS	POST	114	1.00000	0.00027	0.99930	1.00110				

TABLE 28

SUMMARY OF ENVIRONMENTAL FACTORS

FACTORS	n	MEAN	SD	MIN	MAX
DAY (JULIAN)	114	255.9	103.0	82	432
# FILTERS	114	65.1	29.9	15	149
HUM.(%RH)	110*	38.2	12.1	5	65
P_B (mb)	114	1005.4	7.8	981	1031
TEMP.(^oC)	114	21.5	0.9	19	26

*4 missing values
HUM. (%RH) = Humidity (% Relative Humidity)
P_B (mb) = Barometric Pressure (millibars)

TABLE 29

SUMMARY OF SIMPLE LINEAR REGRESSIONS OF BALANCE ZERO AND STANDARD WEIGHT

REGRESSOR	PREDICTOR	Y-INT.	SLOPE	R^2	F-RATIO	p
POST-SESSION ZERO (gm)	DAY	0.00010740	-0.00000037	1.6	1.86 (1,112)	0.172
	#FILTERS WEIGHED	0.00000108	0.00000017	<0.1	0.03 (1,112)	0.848
	HUMIDITY	-0.00011218	0.00000315	1.6	1.81 (1,108)	0.178
	P_B	0.002209	-0.00000219	0.3	0.37 (1,112)	0.551
	TEMPERATURE	0.0019543	-0.00009029	7.8	9.54 (1,112)	0.003
PRE-SESSION 1.0 gm	DAY	1.00004	-0.00000006	0.1	0.06 (1,112)	0.795
	#FILTERS WEIGHED	1.00007	-0.00000065	0.5	0.58 (1,112)	0.546
	HUMIDITY	0.99998	0.00000101	0.2	0.25 (1,108)	0.623
	P_B	1.00105	-0.00000102	0.1	0.10 (1,112)	0.754
	TEMPERATURE	1.00017	-0.00000700	0.1	0.06 (1,112)	0.798
POST-SESSION 1.0 gm	DAY	1.00013	-0.00000047	3.1	3.60 (1,112)	0.057
	#FILTERS WEIGHED	0.99999	0.00000025	0.1	0.08 (1,112)	0.636
	HUMIDITY	0.999803	0.00000526	5.5	6.28 (1,108)	0.013
	P_B	0.999739	0.00000027	<0.1	<0.01 (1,112)	0.932
	TEMPERATURE	1.00154	-0.00007110	5.9	6.99 (1,112)	0.009

P_B = Barometric Pressure

TABLE 29

SUMMARY OF SIMPLE LINEAR REGRESSIONS OF BALANCE ZERO AND STANDARD WEIGHT

REGRESSOR	PREDICTOR	Y-INT.	SLOPE	R^2	F-RATIO	p
POST-SESSION ZERO (gm)	DAY	0.00010740	-0.00000037	1.6	1.86 (1,112)	0.172
	#FILTERS WEIGHED	0.00000108	0.00000017	<0.1	0.03 (1,112)	0.848
	HUMIDITY	-0.00011218	0.00000315	1.6	1.81 (1,108)	0.178
	P_B	0.002209	-0.00000219	0.3	0.37 (1,112)	0.551
	TEMPERATURE	0.0019543	-0.00009029	7.8	9.54 (1,112)	0.003
PRE-SESSION 1.0 gm	DAY	1.00004	-0.00000006	0.1	0.06 (1,112)	0.795
	#FILTERS WEIGHED	1.00007	-0.00000065	0.5	0.58 (1,112)	0.546
	HUMIDITY	0.99998	0.00000101	0.2	0.25 (1,108)	0.623
	P_B	1.00105	-0.00000102	0.1	0.10 (1,112)	0.754
	TEMPERATURE	1.00017	-0.00000700	0.1	0.06 (1,112)	0.798
POST-SESSION 1.0 gm	DAY	1.00013	-0.00000047	3.1	3.60 (1,112)	0.057
	#FILTERS WEIGHED	0.99999	0.00000025	0.1	0.08 (1,112)	0.636
	HUMIDITY	0.999803	0.00000526	5.5	6.28 (1,108)	0.013
	P_B	0.999739	0.00000027	<0.1	<0.01 (1,112)	0.932
	TEMPERATURE	1.00154	-0.00007110	5.9	6.99 (1,112)	0.009

P_B = Barometric Pressure

TABLE 30

MULTIPLE REGRESSION OF STANDARD WEIGHT BY HUMIDITY AND TEMPERATURE

REGRESSOR	PREDICTOR	COEFFICIENTS	R^2	F-RATIO	p
POST-SESSION 1.0 gm	CONSTANT	1.00143	12.1	7.37 (2,107)	0.001
	HUMIDITY	0.000005908		6.69 (1,107)	0.011
	TEMPERATURE	-0.00007656		8.06 (1,107)	0.006

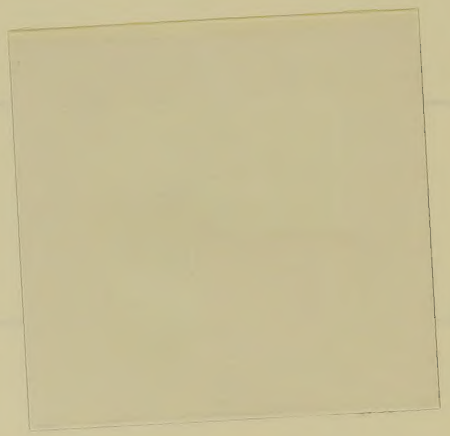


TABLE 31

MULTIPLE REGRESSION MODEL PREDICTED STANDARD 1.0 g MASS MEASUREMENTS

PREDICTOR LEVEL	TEMPERATURE (^{o}C)	HUMIDITY (%)	PREDICTED MASS (g)	MASS DIFFERENCE (g) (STANDARD-PREDICTED)
MIN -MIN	19.0	5.0	1.00000	0.00000
MEAN-MEAN	21.5	38.2	1.00001	-0.00001
MAX -MAX	26.0	65.0	0.99982	0.00018
MIN -MAX	19.0	65.0	1.00036	-0.00036
MAX -MIN	26.0	5.0	0.99947	0.00053

TABLE 32

HI-VOL FILTER REWEIGH STATISTICS

FILTER TYPE	CONDITION	SERIAL WEIGHING	# OF CASES	MEAN (g)	S D (g)	STANDARD ERROR (g)	DIFFERENCE MEAN (g)	DIFFERENCE S D (g)	DIFFERENCE S E (g)	2-TAIL r	2-TAIL PROB.	t VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
ALL	UNEXPOSED	WT. 1	371	4.2652	0.161	0.008	-.0001	.001	.000	1.000	.000	-2.95	370	.003
		WT. 2		4.2653	0.161	0.008								
	EXPOSED	WT. 1	349	4.3088	0.157	0.008	.0003	.001	.000	1.000	.000	6.53	348	<.001
		WT. 2		4.3085	0.157	0.008								
RECTANGULAR	UNEXPOSED	WT. 1	163	4.1837	0.092	0.007	-.0001	.001	.000	1.000	.000	-1.73	162	.086
		WT. 2		4.1837	0.092	0.007								
	EXPOSED	WT. 1	153	4.2643	0.108	0.009	.0001	.001	.000	1.000	.000	1.11	152	.271
		WT. 2		4.2642	0.108	0.009								
CONFIGURA. I	UNEXPOSED	WT. 1	104	4.2700	0.067	0.007	-.0002	.001	.000	1.000	.000	-2.04	103	.044
		WT. 2		4.2701	0.067	0.007								
	EXPOSED	WT. 1	98	4.2783	0.071	0.007	.0004	.000	.000	1.000	.000	8.30	97	<.001
		WT. 2		4.2779	0.071	0.007								
CONFIGURA. II	UNEXPOSED	WT. 1	104	4.3883	0.222	0.022	-.0001	.001	.000	1.000	.000	-1.30	103	.196
		WT. 2		4.3884	0.222	0.022								
	EXPOSED	WT. 1	98	4.4086	0.225	0.023	.0005	.001	.000	1.000	.000	6.88	97	<.001
		WT. 2		4.4082	0.225	0.023								

TABLE 33

EFFECT OF HANDLING ON FILTER MASS

STATISTIC	WITH HANDLING	WITHOUT HANDLING
# OF WEIGHINGS	40	40
$\bar{y}$ FILTER WT. (g)	3.59940	3.6005
SD FILTER WT. (g)	0.00079	0.00006
REGRESSION:		
Y - INTERCEPT	3.60077	3.60060
SD	0.00003	0.00001
SLOPE	-0.00007	-0.000003
SD	<0.00001	<0.000001
r^2 (%)	98.9	51.1
F	3414.5 (1,38)	39.8 (1,38)
P	<0.001	<0.001

TABLE 34

SUMMARY STATISTICS OF CONTROL FILTER MASS OBSERVATIONS

REFERENCE SURFACE	SAMPLE EXPOSURE ANALYTICAL SESSION	WEIGHT IN GRAMS n	$\bar{y}$	SD	MIN	MAX	DIFFERENCE STATISTICS (POST-PRE) n	$\bar{y}$	SD	t	p
RECTANGULAR	PRE	37	4.1408	0.00779	4.1206	4.1496	28	0.00499	0.00988	2.675	0.013
FILTER #1	POST	28	4.1448	0.00244	4.1399	4.1496					
RECTANGULAR	PRE	29	4.1971	0.00171	4.1948	4.2005	29	-0.00113	0.00208	-2.938	0.007
FILTER #2	POST	40	4.1969	0.00206	4.1944	4.2024					
CASCADE	PRE	8	4.9631	0.00197	4.9601	4.9663	8	-0.00184	0.00117	-4.443	0.003
IMPACTION#3	POST	17	4.9636	0.00289	4.9587	4.9681					

| | | |

TABLE 35

SUMMARY STATISTICS OF COLLECTION SURFACE MASSES AND ASSOCIATED ENVIRONMENTAL FACTORS

REFERENCE SURFACE(S)	EFFECTIVE DATES	SURFACE MASS (g)			TEMP. (oC)		RELATIVE HUMIDITY (%)		BAROMETRIC PRESSURE (mb)	
		n	$\bar{y}$	SD	$\bar{y}$	SD	$\bar{y}$	SD	$\bar{y}$	SD
ALL (1,2,3)	82-03-23/ 83-02-23	159	4.2952	0.29066	21.5	1.3	38.6*	12.3*	1007.2	9.3
RECTANGULAR #1	82-03-23/ 11-25	65	4.1425	0.00639	21.8	1.2	43.8	9.6	1005.6	8.1
RECTANGULAR #2	82-07-22/ 83-02-23	69	4.1970	0.00191	21.6	1.3	38.3	12.6	1007.6	9.5
CASCADE IMPACTION#3	82-12-01/ 83-02-23	25	4.9635	0.00260	20.8	1.0	24.5**	5.8**	1010.5	11.0

* SIX MISSING VALUES (N = 153)

** THREE MISSING VALUES (N = 22)

TABLE 36

SUMMARY OF COLLECTION SURFACE MASSES REGRESSED BY ANALYTICAL VARIABLES

REGRESSOR SURFACE MASS IN GRAMS	PREDICTORS	Y-INTERCEPT	SLOPE	R^2	F-RATIO		p
ALL	TEMPERATURE	5.5397	-0.05777	6.2	10.36	(1,157)	0.002
	HUMIDITY	4.70655	-0.010937	23.1	45.38	(1,151)	<0.001
	BAROMETRIC PRESSURE	-0.685	0.004944	2.5	4.04	(1,157)	0.043
	DAYS	3.77412	0.0018257	24.8	51.69	(1,157)	<0.001
	SURFACE TYPE	3.71272	0.33316	66.5	311.21	(1,157)	<0.001
#1	TEMPERATURE	4.13389	0.0003961	0.5	0.33	(1,63)	0.575
	HUMIDITY	4.12047	0.00050353	57.2	84.21	(1,63)	<0.001
	BAROMETRIC PRESSURE	4.28742	-0.00014409	3.3	2.16	(1,63)	0.143
	DAYS	4.13065	0.000051536	33.2	31.36	(1,63)	<0.001
	STORAGE TYPE	4.11859	0.013293	70.4	149.53	(1,63)	<0.001
#2	TEMPERATURE	4.18963	0.0003407	5.7	4.03	(1,67)	0.046
	HUMIDITY	4.19226	0.00012446	65.7	122.50	(1,64)	<0.001
	BAROMETRIC PRESSURE	4.27945	-0.00008186	16.7	13.40	(1,67)	<0.001
	DAYS	4.20273	-0.000018758	34.5	35.30	(1,67)	<0.001
#3	TEMPERATURE	4.98672	-0.0011163	18.0	5.04	(1,23)	0.033
	HUMIDITY	4.96993	-0.00028075	48.3	18.69	(1,20)	0.001
	BAROMETRIC PRESSURE	4.96046	0.00000297	<0.1	0.004	(1,23)	>0.918
	DAYS	4.99471	-0.000084648	79.7	90.57	(1,23)	<0.001

TABLE 37

SUMMARY STATISTICS OF STEPWISE MULTIPLE REGRESSIONS OF COLLECTION SURFACE MASSES

REGRESSOR SURFACE MASS IN GRAMS	PREDICTORS	COEFFICIENTS	R^2	F-RATIO	p
ALL SURFACES	CONSTANT	3.792	66.0		
	SURFACE TYPE	0.300		189.3(1,269)	<0.001
	HUMIDITY	-0.0025		4.1(1,269)	0.041
SURFACE 1	CONSTANT	4.111	89.3		
	STORAGE	0.00602		18.8(1,65)	<0.001
	HUMIDITY	0.00038		101.1(1,65)	<0.001
	DAY	0.00002		10.7(1,65)	0.002
SURFACE 2	CONSTANT	4.192	65.7		
	HUMIDITY	0.00012		122.3(1,89)	<0.001
SURFACE 3	CONSTANT	4.984	82.4		
	DAY	-0.00008		93.7(1,89)	<0.001

TABLE 38

SIMPLE LINEAR REGRESSION OF SURFACE 1 STORAGE TYPES BY ENVIRONMENTAL PREDICTORS

GRAMS

REGRESSOR	PREDICTOR	Y-INTERCEPT	SLOPE	R^2	F-RATIO	p
STORAGE A	TEMPERATURE	4.33352	-0.009361	54.5	13.91 (1,11)	0.004
	HUMIDITY	4.11073	0.0006060	64.7	20.16 (1,11)	0.001
	BAROMETRIC PRESSURE	4.2003	-0.0000679	1.0	0.11 (1,11)	0.744
	DAY	4.09563	0.0002985	94.3	182.34 (1,11)	<0.001
STORAGE B	TEMPERATURE	4.14005	0.0002347	1.8	0.90 (1,50)	0.651
	HUMIDITY	4.13425	0.0002376	82.0	227.28 (1,50)	<0.001
	BAROMETRIC PRESSURE	4.27063	-0.0001248	18.5	11.34 (1,50)	0.002
	DAY	4.15245	-0.0000282	40.1	33.54 (1,50)	<0.001

TABLE 39

SUMMARY STATISTICS OF STEPWISE MULTIPLE REGRESSIONS OF COLLECTION SURFACE 1 MASSES

REGRESSOR SURFACE 1 MASS IN GRAMS	PREDICTORS	COEFFICIENTS	R^2	F-RATIO	p
STORAGE A	CONSTANT	4.095	99.4		
	DAY	0.00024		556.5(1,12)	<0.001
	HUMIDITY	0.00022		81.4(1,12)	<0.001
STORAGE B	CONSTANT	4.136	82.0		
	HUMIDITY	0.00024		227.4(1,76)	<0.001

TABLE 40

SUMMARY OF DIFFERENCE STATISTICS FOR DAYS AND HUMIDITIES
RECORDED ON UNEXPOSED AND EXPOSED SAMPLE ANALYTICAL SESSIONS

GRAMS

REFERENCE SURFACE	EFFECTIVE DATES	DIFFERENCE DAYS (POST-PRE WEIGHS)					DIFFERENCE HUMIDITIES (POST-PRE WEIGHS)				
		n	MEAN	SD	MIN	MAX	n	MEAN	SD	MIN	MAX
#1	82-03-23/ 11-25	28	82.2	13.6	49.0	111.0	28	1.1	17.3	-27.0	27.0
#2	82-07-22/ 83-02-23	29	48.1	27.0	10.0	91.0	26	-12.2	10.3	-35.0	4.0
#3	82-12-01 83-02-23	8	17.1	7.9	10.0	31.0	7	0.0	4.6	-9.0	4.0
1B	82-06-28/ 11-25	16	79.1	14.3	49.0	95.0	16	-10.8	9.9	-27.0	5.0

TABLE 41

MASSES OF THEORETICAL SURFACE FOR VARIOUS LEVELS OF HUMIDITY

HUMIDITY	MEASURED MASS (g)	ADJUSTED MASS (g)
5.0 (MIN)	4.0000	3.9994
38.2 (MEAN)	4.0000	3.9954
65.0 (MAX)	4.0000	3.9922

TABLE 42

MEASURED NET PARTICULATE LOADINGS OF TSP AND PSD COLLECTION SURFACES

(1981-04/1982-03)

SAMPLE TYPE	PARTICLE COLLECTION SURFACE (μ)	n	$\bar{y}$ (mg)	SD (mg)	MIN (mg)	MAX (mg)
TSP	———	1196	113.8	60.9	16.4	367.5
PSD	<1.1	491	28.4	15.9	3.8	116.7
	1.1-2.0	491	7.7	9.4	-46.2	137.7
	2.0-3.3	491	8.3	5.9	-4.7	63.3
	3.3-7.0	491	11.9	10.3	-12.5	94.1
	>7.0	491	21.5	17.9	-1.5	172.5

TABLE 43

TRANSFORMATION OF AN INVALID PSD SAMPLE USING HUMIDITY ADJUSTMENT

RELATIVE PARTICULATE LOADING	UNEXPOSED MEASUREMENT HUMIDITY(%)	EXPOSED MEASUREMENT HUMIDITY(%)	COLLECTION SURFACE (u)	NET PARTICULATE MASS			CUMULATIVE LOADING	
				MEASURED (mg)	ADJUSTED (mg)	%DIFFERENCE (ADJ.-MEAS.)	MEASURED (%)	ADJUSTED (%)
VERY LIGHT (1a)	40	23	<1.1	10.7	12.7	18.7	N/A	72.6
			1.1-2.0	-1.8	0.2	111.1	N/A	74.0
			2.0-3.3	-0.5	1.5	400.0	N/A	82.4
			3.3-7.0	-0.4	1.6	500.0	N/A	91.7
			>7.0	-0.5	1.5	400.0	N/A	100.1

TABLE 44

EFFECT OF HUMIDITY ON CALCULATED PSD SAMPLE NET LOADING AND CONCENTRATION

RELATIVE PARTICULATE LOADING	UNEXPOSED MEASUREMENT HUMIDITY(%)	EXPOSED MEASUREMENT HUMIDITY(%)	COLLECTION SURFACE(μ)	NET PARTICULATE MASS			PARTICULATE CONCENTRATION		
				MEASURED (mg)	ADJUSTED (mg)	%DIFFERENCE (ADJ.-MEAS.)	MEASURED (mg)	ADJUSTED (mg)	%DIFFERENCE (ADJ.-MEAS.)
LIGHT (1a)	40	23	<1.1	14.2	16.2	14.1	17.4	19.7	13.2
			1.1-2.0	3.8	5.8	52.6	4.7	7.1	51.1
			2.0-3.3	4.2	6.2	47.6	5.2	7.6	46.2
			3.3-7.0	6.0	8.0	33.3	7.4	9.8	32.4
			>7.0	10.7	12.7	18.7	13.1	15.6	19.1
							47.8	59.8	25.1
LIGHT (1b)	23	40	<1.1	14.2	12.2	-14.1	17.4	15.0	-13.8
			1.1-2.0	3.8	1.8	-52.6	4.7	2.2	-53.2
			2.0-3.3	4.2	2.2	-47.6	5.2	2.7	-48.1
			3.3-7.0	6.0	4.0	-33.3	7.4	4.9	-33.8
			>7.0	10.7	8.7	-18.7	13.1	10.7	-18.3
							47.8	35.5	-25.7
AVERAGE (2a)	40	23	<1.1	28.4	30.4	7.0	34.8	37.3	7.2
			1.1-2.0	7.7	9.7	26.0	9.4	11.9	26.6
			2.0-3.3	8.3	10.3	24.1	10.2	12.6	23.5
			3.3-7.0	11.9	13.9	16.8	14.6	17.0	16.4
			>7.0	21.5	23.5	9.3	26.4	28.8	9.1
							95.4	107.6	12.8
AVERAGE (2b)	23	40	<1.1	28.4	26.4	-7.0	34.8	32.4	-6.9
			1.1-2.0	7.7	5.7	-26.0	9.4	7.0	-25.5
			2.0-3.3	8.3	6.3	-24.1	10.2	7.7	-24.5
			3.3-7.0	11.9	9.9	-16.8	14.6	12.1	-17.1
			>7.0	21.5	19.5	-9.3	26.4	23.9	-9.5
							95.4	83.1	-12.9

TABLE 45

EFFECT OF HUMIDITY ON CLACULATED PSD SAMPLE CUMULATIVE PERCENT LESS THAN AND MASS MEDIAN DIAMTER

RELATIVE PARTICULATE LOADING	UNEXPOSED MEASUREMENT HUMIDITY(%)	EXPOSED MEASUREMENT HUMIDITY(%)	COLLECTION SURFACE(u)	CUMULATIVE % LESS THAN*			MASS MEDIAN DIAMETER				
				MEASURED (%)	ADJUSTED (%)	%DIFFERENCE (ADJ.-MEAS.)	MEASURED		ADJUSTED		%DIFFERENCE ($\bar{y}$ ADJ.-$\bar{y}$MEAS.)
							$\bar{y}(\mu)$	(σg)	$\bar{y}$ (μ)	(σg)	
LIGHT (1a)	40	23	<1.1	0.0	0.0	0.0	2.27	7.2	2.40	5.6	5.7
			1.1-2.0	36.4	32.9	-9.6					
			2.0-3.3	46.2	44.8	-3.0					
			3.3-7.0	57.1	57.5	0.7					
			>7.0	72.6	73.9	1.8					
LIGHT (1b)	23	40	<1.1	0.0	0.0	0.0	2.27	7.2	2.02	15.8	-11.0
			1.1-2.0	36.4	42.3	16.2					
			2.0-3.3	46.2	48.5	5.0					
			3.3-7.0	57.1	56.1	-1.8					
			>7.0	72.6	69.9	-3.7					
AVERAGE (2a)	40	23	<1.1	0.0	0.0	0.0	2.27	5.7	2.32	6.1	2.2
			1.1-2.0	36.5	34.7	-4.9					
			2.0-3.3	46.4	45.8	-1.3					
			3.3-7.0	57.1	57.5	0.7					
			>7.0	72.4	73.3	1.2					
AVERAGE (2b)	23	40	<1.1	0.0	0.0	0.0	2.27	5.7	2.17	8.3	-4.4
			1.1-2.0	36.5	39.0	6.8					
			2.0-3.3	46.4	47.4	2.2					
			3.3-7.0	57.1	56.7	-0.7					
			>7.0	72.4	71.3	-1.5					

*Cumulative Percentage Less Than Size Range
σg = Geometric Standard Deviation

TABLE 46

SUMMARY STATISTICS OF HUMIDITY MEASUREMENTS OBTAINED USING HYGROGRAPH AND SLING PSYCHROMETER

RELATIVE HUMIDITY (%)

# OF OBSERVATIONS	HYGROGRAPH		SLING PSYCHROMETER		DIFFERENCE STATS. (PSYCHROMETER-HYGROGRAPH)				REGRESSION STATISTICS				
	$\bar{y}$	SD	$\bar{y}$	SD	$\bar{y}$	SD	t	p	Y-INTERCEPT	SLOPE	R^2	F-RATIO	p
47	27.4	2.9	34.4	4.2	6.9	4.5	10.64	<0.001	21.119	0.18355	7.0	3.14	0.080

PART 3

INTERLABORATORY COMPARISON

The TSP network set up by the UAEG was designed to complement, not to duplicate, TSP sites operated by the OME. However, in 1982-06 a TSP sampler was installed at the OME air quality station at the corner of Barton and Sanford streets in Hamilton. This sampler was operated concurrently with OME samplers. All sample analyses and primary data reduction were conducted independently by the respective groups. The final particulate concentrations of eleven concurrent sample pairs formed the data base of the comparison presented in Table 47. A two-tailed Student's t-test did not detect a significant difference between UAEG and OME data [$p = 0.1924$]. Simple linear regression of UAEG by OME particulate data indicated that there was very good agreement between the two groups [slope = 1.01, $p<0.001$], though the UAEG readings averaged 6.32 ug/m^3 higher than the OME values; the regression model explained 85.1% of the variation in reported TSP values.

PART 4

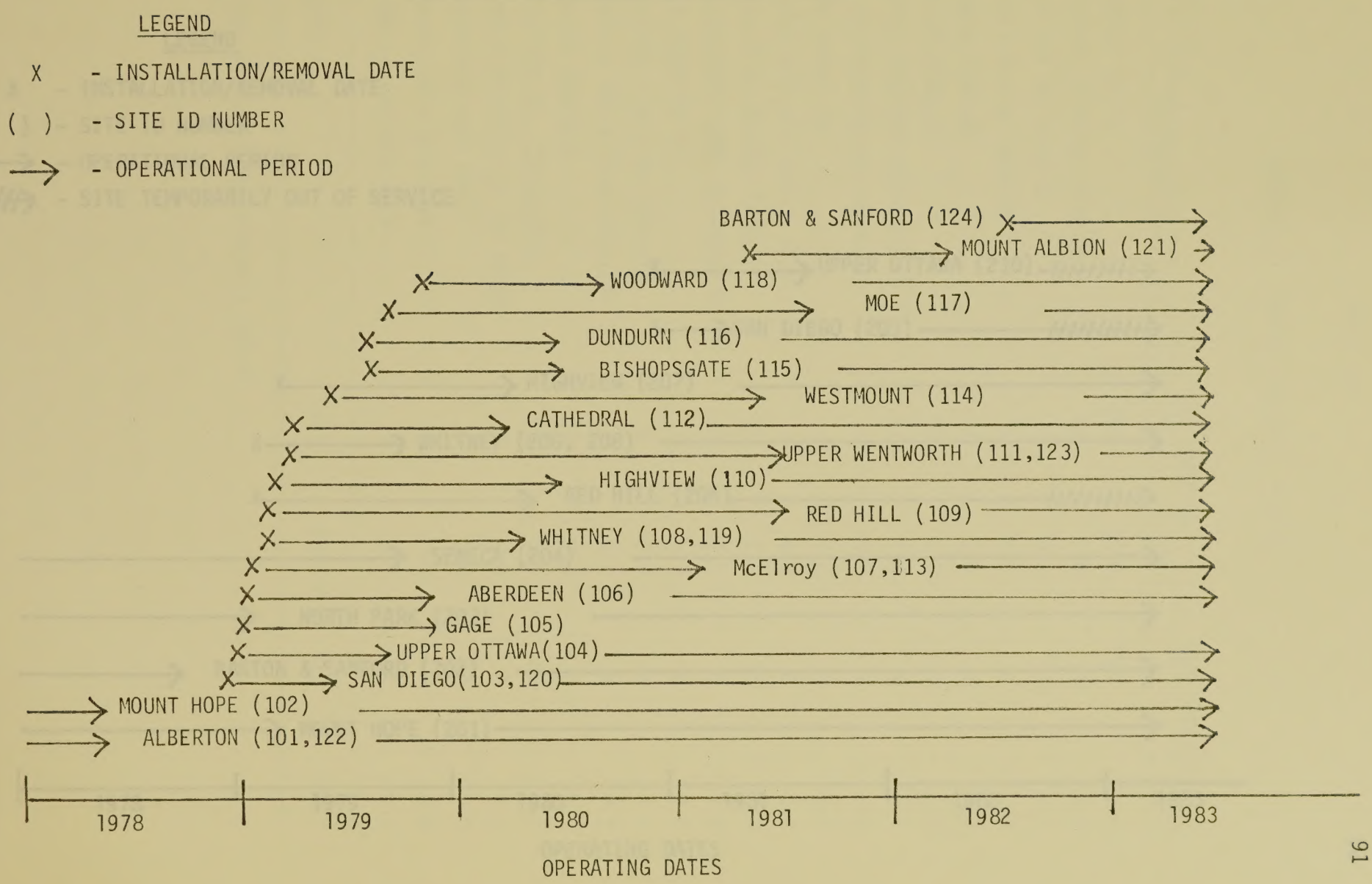
SAMPLING SUCCESS RATES

The existing high-volume particulate sampling network was expanded between January 1979 and June 1982. Figures 10 and 11 present summaries of operational TSP and PSD sites, respectively.

In April 1981, the data management system was upgraded to reduce manual data manipulation and calculations. All raw data was coded and keypunched onto computer files. At this time, we developed a list of special codes to identify valid and invalid samples. Invalidity codes specified problems that resulted in the sample being rejected. Table 48 presents a summary of these codes and the frequency of occurrence for both TSP and PSD samples attempted between April 1981 and May 1982. Sampling success rates were 85.0 and 84.3% for TSP and PSD, respectively. Flow record problems accounted for 40% of the invalid TSP samples; negative loadings accounted for 27% of invalid PSD samples.

FIGURE 10

TSP NETWORK (UAEG) OPERATIONAL SITE SUMMARY



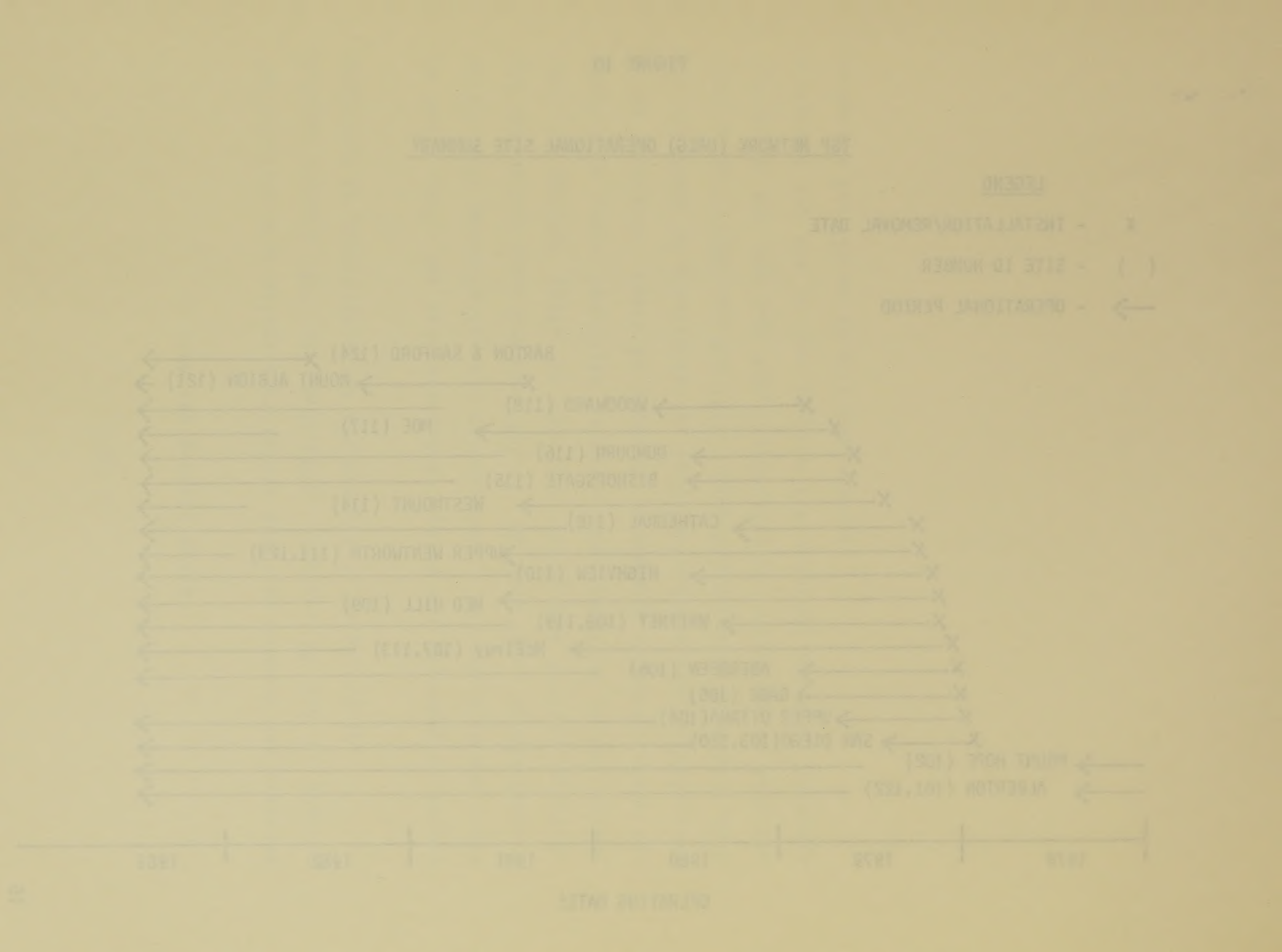


FIGURE 11

PSD NETWORK OPERATIONAL SITE SUMMARY

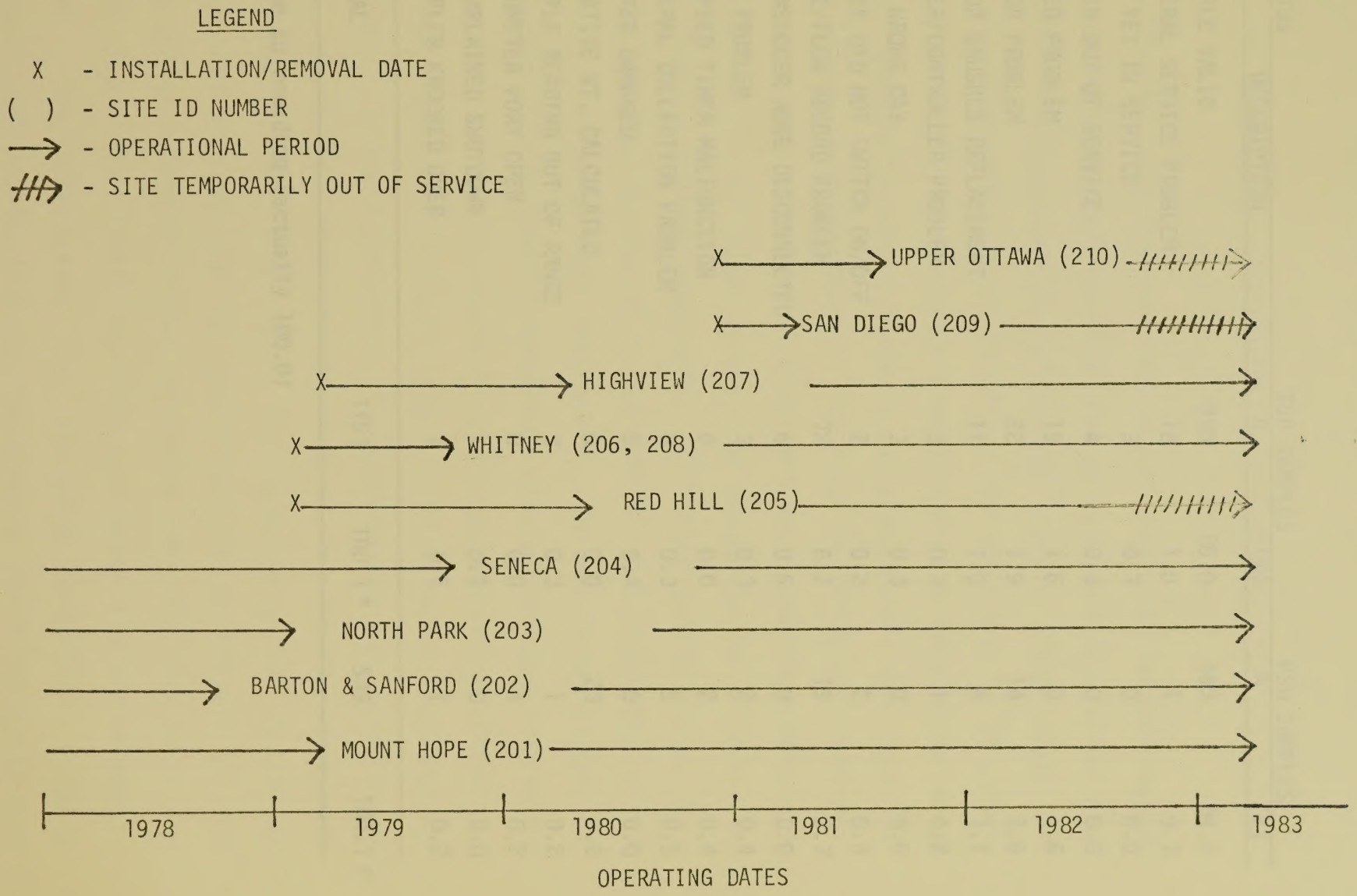


TABLE 48

SUMMARY OF SAMPLE VALIDITY STATUS

STATUS CODE	STATUS DESCRIPTION	TSP SAMPLES n	TSP SAMPLES (%)	PSD SAMPLES n	PSD SAMPLES (%)
000	SAMPLE VALID	980	85.0	463	84.3
100	GENERAL SERVICE PROBLEM	12	1.0	4	0.7
110	NOT YET IN SERVICE	3	0.3	0	0.0
120	TAKEN OUT OF SERVICE	4	0.3	0	0.0
200	POWER PROBLEM	19	1.6	9	1.6
300	MOTOR PROBLEM	22	1.9	14	2.6
310	MOTOR BRUSHES REPLACEMENT	11	1.0	6	1.1
400	TIMER/CONTROLLER PROBLEM	3	0.3	1	0.2
410	RAN WRONG DAY	3	0.3	0	0.0
420	TIMER DID NOT SWITCH ON/OFF	2	0.2	2	0.4
500	TIME/FLOW RECORD PROBLEM	72	6.2	15	2.7
520	TRANSDUCER HOSE DISCONNECTED	6	0.5	0	0.0
530	PEN PROBLEM	3	0.3	2	0.4
540	ELAPSED TIMER MALFUNCTION	0	0.0	2	0.4
600	GENERAL COLLECTION PROBLEM	3	0.3	5	0.9
620	FILTER DAMAGED	5	0.4	0	0.0
640	NEGATIVE WT. CALCULATED	0	0.0	23	4.2
650	SAMPLE READING OUT OF RANGE	3	0.3	1	0.2
670	MANOMETER PORT OPEN	0	0.0	1	0.2
900	UNEXPLAINED SHUTDOWN	1	0.1	0	0.0
910	SAMPLER KNOCKED OVER	1	0.1	1	0.2
	TOTAL	1153	100.1*	549	100.1*

*Due to rounding (actually 100.0)

PART 5

SUMMARY OF TSP SAMPLE MEASUREMENTS

Table 49 presents the calculated precision of measurements required to determine the Total Suspended Particulate concentration. The procedural precision values were based on calculated standard deviations, standard errors, or, in the case of time precision, the limitations associated with recording chart scales. For each variable, a number of procedures were used to estimate variation in measurement. "Orifice calibration" referred to the technique used to convert static pressure readings obtained in the field to "true" flow rates, as measured by a positive displacement meter. The precision of this calibration was estimated to be 0.1 inches of water static in pressure, which converts to 1.0 cfm at a flow rate of 47 cfm, as shown Figure 4. The "transducer calibration" precision related to the variation inherent in the orifice-transducer field calibration method of relating static pressure ["true" flow] to flow rates recorded by the transducer. Table 8 presents the summary of TSP calibration regressions, where the mean standard error for the y-intercepts was calculated to be 2.4 cfm. The precision of duplicate calibrations was calculated as the standard deviation of the differences of operational flows recorded in 1980 and 1981, as presented in Table 10. Chart reading precision was estimated to be 0.5 cfm. The difference in standard deviation between operators was only 0.05, but the recording chart interval was

2 cfm, making it impossible to interpolate recorded flows closer than 0.5 cfm. Overall precision of flow measurement was estimated to be 3.4 cfm.

The determination of sample duration required the reading of elapsed time from the transducer charts. The mean difference standard deviation of the times determined by the three operators presented in Table 21 was 1.0 minutes. The chart time interval was 15 minutes, limiting estimates of elapsed time to within 5 minutes of the actual sampling duration.

Net particulate loading depended on the ability of the balance to accurately determine pre- and post-sampling filter weights. The major influences in the determination of net loading were balance and filter stability. Balance stability was monitored by instrument zeroing and repetitive weighings of a Class "S" standard weight. The standard deviation of the differences were calculated to be 0.3 mg and 0.3 mg, respectively. Approximately ten percent of all filters were reweighed; the difference standard deviation was calculated to be 1.0 mg for both pre-sample and post-sample filter reweighs. The effect of filter humidity conditioning was estimated to be 2.1 mg, the annual standard deviation of collection surface tare masses predicted by the multiple linear regression model of Surface 2 (Sections 2.3.2.2 and 2.3.2.3, and Table 37).

Table 50 presents estimates of precision, calculated for each

major TSP variable, based on the collective estimates calculated for the individual procedures. Overall precision was 3.4 cubic feet per minute for flow, 5.0 minutes for sample duration, and 2.6 mg for net particulate loading.

Table 50 also presents the effect of precision on the determination of TSP concentrations. Total precision was shown to be 4.2 ug/m^3, which was equivalent to a total error of 7.8%, based on the Hamilton TSP annual mean of 47.2 ug/m^3 [1981-04-22/82-04-17]. The major contributing factors were flow and net loading, whose effects accounted for approximately 99 percent of the imprecision. Considerable improvement to precision would be gained by reducing transducer calibration and filter tare mass error. Transducer calibration precision might be improved by converting measured flow rates to reference conditions [25^{o}C and 760 mm Hg] before determination of "true" sample flow rates. Filter tare mass precision would be improved by reducing duration of storage prior to post-exposure gravimetric analysis, and by introducing a statistically-derived correction of tare mass for changes in balance room relative humidity.

TABLE 49

SUMMARY OF MEASUREMENT PRECISION FOR TSP VARIABLES

MEASUREMENT VARIABLE	MEASUREMENT PROCEDURE	ESTIMATED PRECISION
FLOW (cfm)	ORIFICE CALIBRATION	1.0
	TRANSDUCER CALIBRA.	2.4
	DUPLICATE CALIBRATION	2.2
	CHART READING	0.5
	TOTAL	3.4*
TIME (min)	CHART READING	5.0
NET LOADING (mg)	ZEROING	0.3
	STANDARD WEIGHT	0.3
	FILTER REWEIGHS	
	PRE-EXPOSURE	1.0
	POST-EXPOSURE	1.0
	HUMIDITY EFFECT	2.1*
	TOTAL	2.1**

* Applicable to yearly data only.

**Computed as the positive square root of the sum of the squares of the individual component precisions.

TABLE 50

EFFECT OF MEASUREMENT PRECISION ON TSP CONCENTRATIONS

MEASUREMENT VARIABLE	PRECISION	PREDICTED VALUES	CALCULATED CONC^{a} ($\mu g/m^3$)	CONC^{a} SD ($\mu g/m^3$)
FLOW	3.4 cfm	43.8 cfm	58.7	
		47.2 cfm	54.5	3.95
		50.6 cfm	50.8	
TIME	5.0 min	1435 min	54.6	
		1440 min	54.5	0.15
		1445 min	54.3	
NET LOADING	2.6 mg	102.3 mg	53.1	
		104.9 mg	54.5	1.40
		107.5 mg	55.9	
TOTAL % ERROR				4.19* 7.8

* Computed as the positive square root of the sum of squares of the individual component precisions.
All calculations are based on the following values unless otherwise indicated:

FLOW RATE = 47.2 cfm (mean flow 1980, 1981)

SAMPLING TIME = 1440 min (24 hours)

NET LOADING = 104.9 mg (mean loading of samples collected 810422/820417)

TSP CONCENTRATION = 54.0 $\mu g/m^3$ (mean concentration of samples collected 810422/820417)

PART 6

SUMMARY OF PSD SAMPLE MEASUREMENTS

Table 51 presents the calculated precisions of the individual measurement variables required to determine the particulate concentrations of the five discrete PSD Size Fractions. The flow measurement precision was determined to be the standard deviation of the differences between pre- and post-sample flow field calibrations, as presented in Table 16. This value was 0.498 inches of water, which converted to 0.229 cfm, as indicated in Figure 7. The variation in manufacturer standardization was assumed to be minimal (<0.1 cfm), and was not considered in measurement evaluation. The sampling time measurement precision was assumed to be 5.0 minutes due to the recording chart scale, as noted in Part 5. Samplers equipped with digital elapsed timers were considered to be more precise; therefore, chart recorded sample durations were accepted as the "worst case" for further analysis. Balance stability precision was considered to be the standard deviation of the differences between pre- and post-session zeroing of the instrument, and pre- and post-session massing of a standard 1.0 g mass; these were 0.3 mg and 0.3 mg, respectively (from Table 27). Filter weighing precision, estimated as the standard deviation of differences between initial and reweigh mass observations, was 1.0 mg for all types of collection surfaces (from Table 32). The humidity effect was estimated to be the annual standard deviation of collection

surface tare masses predicted by the multiple regression model of Surface 2 (Table 37).

Table 52 presents the effects of measurement precision on mean PSD concentration. The overall precision of each PSD size fraction was approximately 3.0 ug/m^3. The percentage error was calculated using the mean concentrations of each fraction for samples collected between April 1981 and April 1982. The estimated error varied between 8.3% and 28.9%. The lowest errors were associated with the fine and coarse PSD fractions, which collected the greatest particulate loadings. Larger errors [19.4 to 28.9%] were associated with the mid-sized particulate fractions.

The major contributor to PSD measurement imprecision was the humidity effect, discussed in detail in Section 2.3.2.3. This effect has been reduced by minimizing collection surface storage duration; further improvements in precision are expected with the introduction of statistical corrections to standardize collection surface masses measured under differing relative humidities. For the purpose of this report, the PSD measurements were used to calculate mean annual mass median diameters. Estimates of MMD were less affected by humidity than estimates of particulate concentration. The annual [1982] mean difference in relative humidity between unexposed and exposed surface mass measurements was -1.5 percent [SD = 15.6]. The error in estimated annual MMD would be expected to be less than 10% (see Table 45).

TABLE 51

SUMMARY OF PSD MEASUREMENT VARIABLE PRECISIONS

MEASUREMENT VARIABLE	MEASUREMENT PROCEDURE	PSD MASS MEDIAN DIAMETER (μ) <1.1	1.1-2.0	2.0-3.3	3.3-7.0	>7.0
FLOW (cfm)	WITHIN SAMPLE	0.229	0.229	0.229	0.229	0.229
	FACTORY CALIBRATION	<0.1	<0.1	<0.1	<0.1	<0.1
	TOTAL	0.229	0.229	0.229	0.229	0.229
SAMPLE TIME (min)	CHART READING	5.0	5.0	5.0	5.0	5.0
	ELAPSED TIMER	<1.0	<1.0	<1.0	<1.0	<1.0
	TOTAL	5.0	5.0	5.0	5.0	5.0
NET LOADING (mg)	BALANCE ZERO	0.3	0.3	0.3	0.3	0.3
	STANDARD WEIGHT	0.3	0.3	0.3	0.3	0.3
	FILTER REWEIGHS					
	CONFIGURATION I			1.0		1.0
	CONFIGURATION II		1.0		1.0	
	BACKUP	1.0				
	HUMIDITY EFFECT	2.1*	2.1*	2.1*	2.1*	2.1*
	TOTAL	2.4**	2.4**	2.4**	2.4**	2.4**

* Applicable to yearly data only.

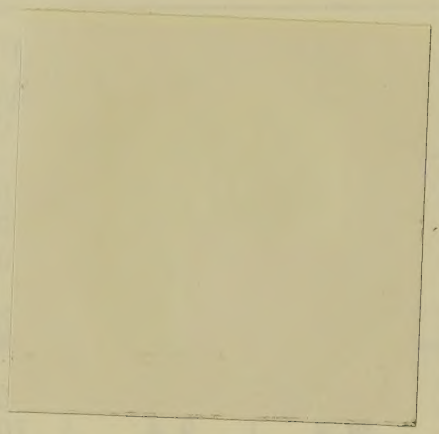
** Computed as the positive square root of the sum of squares of the individual variable precisions.

TABLE 52

EFFECT OF MEASUREMENT PRECISIONS ON MEAN PSD CONCENTRATIONS

MEASUREMENT VARIABLE	TYPICAL VALUES	PSD CONCENTRATIONS ($\mu g/m^3$) FOR MASS MEDIAN DIAMETERS (μ) <1.1	1.1-2.0	2.0-3.3	3.3-7.0	>7.0
FLOW (cfm)	19.771	34.9	9.6	10.5	14.4	27.2
	20.000	34.5	9.4	10.4	14.2	26.9
	20.229	34.1	9.3	10.3	14.1	26.6
	SD	0.40	0.15	0.10	0.15	0.30
TIME (min)	1435	34.5	9.5	10.5	14.3	26.9
	1440	34.4	9.4	10.4	14.2	26.9
	1445	34.3	9.4	10.4	14.2	26.8
	SD	0.10	0.06	0.06	0.06	0.06
NET LOADING (mg)	25.7	31.5				
	28.1	34.5				
	30.5	37.4				
	SD	2.95				
	5.3		6.5			
	7.7		9.4			
	10.1		12.4			
	SD		2.95			
	6.1			7.5		
	8.5			10.4		
	10.9			13.4		
	SD			2.95		
	9.2				11.3	
	11.6				14.2	
	14.0				17.2	
	SD				2.95	
	19.5					23.9
	21.9					26.9
	24.3					29.8
	SD					2.95
TOTAL		2.98*	2.95*	2.95*	2.95*	2.96*
MEAN SAMPLE CONCn ($\mu g/m^3$)		35.6	10.2	10.5	15.2	27.3
% ERROR IN CONCn		8.3	28.9	28.1	19.4	10.8

* Computed as the positive square root of the sum of squares of the individual variable precisions.



PART 7

HIGH-VOLUME SUSPENDED PARTICULATE SAMPLING SUMMARY

The overall measurement precision of TSP data was estimated to 7.8% of the mean annual [1981-82] Hamilton TSP concentration. This level of precision is considered to be adequate, as measurement agreement with OME is close. Slight improvements in precision would be expected with the introduction of statistically derived mass adjustment to compensate for changes in measurement ambient relative humidity. TSP precision may also be improved by converting all calibration and sample air flows to standard reference conditions [20^{o}C and 760 mm Hg]. Valid TSP measurements account for 85 percent of sampling attempts.

Calculated mean annual PSD mass median diameter estimate errors were less than 10 percent, and were considered acceptable for human exposure estimates. Estimates of precision for PSD particulate concentrations range between 8.3 and 28.9% of the mean annual [1981-82] concentrations for Hamilton. Precision of measurement of particulate concentration varied inversely with particulate concentration. The largest errors were associated with mid-range particle size fractions and samples which collected low levels of suspended particulates. PSD measurement precision improved with increased net particulate loading. The introduction of a statistically derived mass adjustment for changes in ambient measurement humidity is expected to reduce overall PSD

concentration error by 50 percent, and to improve the current sampling success rate of 84 percent.

PART 8

REFERENCES

Code of Federal Regulations, 40(50.11): July 1, 1975. Appendix B, pp. 12-16.

Environment Canada (1973), "Standard Reference Method for the Measurement of Suspended Particulates in the Atmosphere". EPS 1-AP-73-2, Air Pollution Control Directorate.

Andersen 2000 Inc. (1976), "Operating Manual For Andersen 2000 Inc. High Volume Particles Sizing Samplers". TR #76-900018.

HAMILTON PUBLIC LIBRARY
3 2022 21336432 2